ANALYSIS

OF

A COURSE OF LECTURES

ON

NATURAL AND EXPERIMENTAL

PHILOSOPHY,

VIZ.

1. PROPERTIES OF MATTER,
2. MECHANICS,
3. CHEMISTRY,
4 and 5. PNEUMATICS,
6. HYDROSTATICS,
7. ELECTRICITY,
8. ELECTRICITY,
9. OPTICS,
10. USE of the GLOBES, &c.
11 and 12. ASTRONOMY.

EIGHTH EDITION.

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As many who attend this Courſe may not have made PHILOSOPHY a *previous ſtudy*, it may be ſuppoſed that many of its uſeful parts will eſcape the memory; 'tis therefore at the requeſt of *thoſe* I have drawn up this ſhort Analyſis, by a ſhort look at which, any particular propoſition or experiment will eaſily be recollected.

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LECTURE I.

On the general Properties of Matter.

AN hundred and fifty years are ſcarce elapſed ſince the clouds of prejudice, which had long overſpread the world, began to clear up, and men were convinced, by cultivating the ſciences and attending to nature, that no *fanciful conjectures* could ever lead them to the true cauſes of thoſe various phænomena that inceſſantly, and every where, meet the obſerver's eye; but that the narrow limits of the human underſtanding, confine the courſe of our reſearches to *one ſingle path*—namely, that of *experiment*, or the *uſe of our ſenſes*. Yet, in this ſhort period, natural philoſophy hath riſen to an high pitch of improvement, and may with truth be ſaid to have made much greater advances towards perfection ſince the experimental method was introduced, than in the many ages before.

Becaufe many bodies are reducible to water, *this* element has been thought, by many able philofophers, to be the primary origin of all matter ; and that bodies differ only as they contain more or lefs *particles*, or *pores* differently difpofed. We find, indeed, the decompofition of bodies finite, being unable to carry it beyond a certain limit ; if we attempt to go further, we are always ftopt by fubftances in which we can produce *no change*, which are incapable of being refolved into others, and which ftand as fo many *firm barriers* obftructing our progrefs. To thefe fubftances we affix therefore, more properly, the name of principles, or firft elements, and they are *earth*, *air*, *fire*, and *water*.

☞ Mr. Cavendifh has lately difcovered a method of generating *water* by inflaming a mixture of common and inflammable air in a clofe veffel.

The properties that are common to all thefe elements, are : 1ft, *Divifibility*, *i. e.* the particles of each element are fo fmall, that they efcape the fcrutiny of our beft glaffes. A candle will fill a fphere of four miles in diameter with particles of light in a fecond of time. Two ounces of affa-fœtida, nicely weighed, may lie expofed to the air, and have its particles carried off by it for a fortnight together, and yet it will not lofe the thoufand part of a grain of its original weight. Eight grains of gold will cover a wire completely 13,000 yards in length. A grain of copper diffolved in a jill of aqua fortis, will cover as much polifhed iron with a fine fkin of copper as the aqua fortis will wet : Nay, Lewenhock difcovered with his microfcope more living animalculæ in the milt of one cod-fifh, than there are men, women, and children, on the whole earth.

2dly, The matter of which thefe elements are formed is *impenetrably hard*. If we pound the moft brittle fubftance to the moft impalpable powder its original particles ftill remain unhurt. If water has no bed of air to fall upon, it will fall upon the glafs in which it is inclofed

like a piece of iron and make a loud click; a column of air falling on a plate of an air-pump will give a report as loud as a gun: Nay, elementary fire, ſubtil as it is, ſtrikes the bones, in the electric ſhock, like a ſolid body; and lightning penetrates the hardeſt ſubſtances.

3dly, Matter is *inert*, *i. e.* can neither move, nor ſtop, of itſelf. A ball on the whirling-table, neither begins to move when the table moves, nor ſtops when the motion of the table is ſtopped. Give a ſudden puſh to a bowl of water, and the fluid will fly over the bowl in a contrary direction; but if you turn ſwiftly round with the bowl in your hand, and ſtop ſuddenly, the water will fly over the bowl the way it was going. The *inertia* increaſes as the quantity of matter. A man lying with a large anvil on his breaſt, will not be hurt when a blackſmith ſtrikes upon it with a large hammer, with all his ſtrength; but if he had an anvil only a pound weight upon his breaſt, the firſt ſtroke of the blackſmith would kill him. The *vis inertiæ* of the large anvil makes its reſiſtance equal to the ſtroke of the hammer, ſo that the anvil may be ſaid to ſtrike the hammer as forcibly as the hammer ſtrikes it; and hence the difficulty of putting large bodies in motion. Theſe are but ſmall inſtances of thoſe three laws of nature which Sir Iſaac Newton found univerſal, viz. *That matter is perfectly indifferent to either reſt or motion.* 2dly, *That bodies move in proportion to the force that acts on them.* And 3dly, *That action and re-action are equal, and contrary.*

4thly, *Matter attracts, and is attracted*; *i. e.* All parts of matter have a tendency toward each other. A plumb line on the ſide of a mountain is drawn out of its perpendicular by the attraction of the mountain. Two cork balls, ſwimming on water, run together with an accelerated motion, and ſtick together. Water riſes above its level againſt the ſide of the bowl which holds it; and alſo in capillary or ſmall tubes: And hence the reaſon why water riſes in ſponge, ſand, between glaſs planes, &c. for all theſe may be conceived as made up of capillary tubes. Two planes of lead, marble, glaſs, iron, &c.

thruſt cloſe together, ſtick ſo, that exceſſive force alone can ſeparate them. 'Tis this *attraction of cohesion* that makes all bodies cohere, or maintain any diſtinct form; and as ſome parts of matter attract more forcibly than others, iron becomes heavier, and more compact, than wood; gold and platina have more particles in leſs room than any other metal; lead is different from ſtone, becauſe its particles attract one another more forcibly; ſo that all that variety which we ſee in both mineral, animal, and vegetable ſubſtances, ariſes from the different combinations of the four elements, the different degree of attraction in the particles of each, and in the different diſpoſition of the pores, or interſtices, that are between the particles of which they are compoſed. For the particles of the heavieſt and lighteſt bodies are all of the ſame weight, as may be proved by dropping a piece of gold, and a feather, down a tall glaſs that has no air in it to reſiſt their paſſage. Fire can deſtroy this coheſive quality in bodies, for a time, but makes no alteration in the original particles of bodies. It will inſinuate itſelf into gold, and ſeparate its particles, ſo as to make it into a fluid. Water and air are kept in a ſtate of fluidity by heat. Fire increaſes (perhaps cauſes) the repulſive qualities of all bodies. Metals ſwell with a ſmall degree of heat, as may be proved by the pyrometer. All nature is kept in motion by it; even blocks and ſtones ſwell by the heat of the day, and contract by the cold of the night. It gives water ſo repulſive a quality, that it flies off in ſteam. Air is ſo ſwelled by it, that, to keep up its equilibrium, it is perpetually agitated by winds and ſtorms. Fire is the only *eſſential fluid*, and the cauſe of fluidity in other bodies, by ſeparating their parts. However, there ſeems to be a repulſive quality common through nature, independently of fire. 'Tis ſaid, "where the ſphere of attraction ends, repulſion begins." The north pole of a magnet, at one-tenth of an inch from a ſuſpended needle, attracts it; but at five-tenths from it, it repels it. A glaſs tube rubbed with a dry hand, will alternately attract and repeal feathers, leaf gold, and other light bodies. A ſmall needle will lie on the ſurface of water by its repulſion; flies run over it without wetting their feet, and a drop of oil will be ſuſ-

tained by its repulfion ; without ever touching the furface of the water. The rays of light are faid to be repelled from the furface of a looking-glafs, &c. however I doubt the univerfality of this principle.

5thly, *Elective attraction*, or the tendency which *one* part of matter has to unite with fome other *particular* part in preference to every other part of matter, forms the grand bafis of Chemiftry.—Thus, water rufhes into union with fpirit, but not with oil.——Acids have the ftrongeft affinity to phlogifton and alkali.——Air attracts water with greater avidity than falt, fo that frefh water is abforbed by it from the furface of a falt fea, &c. Of the elective kind of attraction alfo is that of magnetifm, becaufe it only attracts iron, fteel, and itfelf; fome hold magnetifm and electricity as relations, becaufe fteel ftruck by lightning, or a ftrong fhock of electricity, acquires polarity and magnetic attraction. One Magnus, a fhepherd, firft difcovered this wonderful ftone from its fticking to the iron in his fandals, and from him it had its name: Its attraction is at two oppofite points, called its poles, and if the ftone was broke into a thoufand pieces, each piece would have its attracting poles: This attraction is ftrongeft in contact, and diminifhes by a proportion not yet found out; but that point of a ftone which attracts one end of a touched needle will repel the other. Flavius Gio, of Naples, about 350 years ago, firft difcovered that a piece of fteel rubbed on it, and then fufpended, had the property of pointing north and fouth, and thence applied it to navigation. An hundred years after, it was found by Sebaftion Cabot to have varied above 11 degrees eaft. It continued to vary towards the eaft at the rate of about one degree in feven years, till the needle formed an angle with the meridian of 30 degrees. It then returned towards the weft at the fame rate, fo that about the year 1600 the line of *no variation* paffed over England, the needle pointing then directly north and fouth. Since that time it has continued varying towards the weft, and with us at this time the needle is 22 degrees 48 minutes weft. It is probable it will continue to vary weftward till it makes an angle with the meridian of 30 degrees, (as it did at

its eaftern extremity) and then return weftward, finifhing its revolution in between 900 aud 1000 years. A line of no variation at prefent paffes fouthward near Madagafear, doubles the Cape of Good Hope, flopes acrofs the Atlantie, touching Brazil, and ferpentine paffes through Canada, over the Weftern Lakes, and terminates at the north magnetieal pole, fituated about 30° from that of the earth, in the meridian of California. From thence the *line of no variation* proceeds over the earth's north pole, inelining eafterly over Siberia, Tartary, China, the Ladrone Ifles, and New Holland, and then arrives at the fouth magnetie pole, fituated to the fouth-eaft of Van Deiman's Land, about lat. 56° fouth, and 180° weft long. from London. Thefe lines, as well as poles, move weftward at prefent; and Captain Cook in his laft voyage, came fo near the fouth magnetie pole, that his compafs needle turned half round in 24 hours failing—and the dipping needle ftood almoft perpendieular. If a piece of fteel of fpring temper be balaneed on a point horizonally, fo foon as it has received magnetic virtue, it dips or inclines, fo as to point in a ehord to the north or fouth magnetic pole of the earth: But if equidiftant from both, it eontinues horizontal, like a balanced bar moved from one end to the other of a long artifieial magnet.

The theory of making *artificial magnets* is derived from an *effluvium* fuppofed to flow from one pole of the magnet to the other,—the exiftence of which is made very probable, by fteel filings feattered over a plate of window glafs, with a *bar magnet* under it, when the effluvium in its paffage from one pole to the other influenees the filings into many parallel and beautiful curves. Two pieces of fteel, *fpring temper*, made in fhape of horfe-fhoes, and their ends put together; if then two *bar magnets* juft feparated, and of oppofite poles, or an *horfe-fhoe* or *natural* magnet be rubbed over them all the fame way, *polarity* and *attraction* will be communieated to the fteel; but if the two pieces be put together, fo that the two repelling ends are together, they attract ftrongly: And henee feveral bars thus united

form a very ſtrong magnet.—If a piece of iron, as a *conductor*, be put between the two poles, the magnet will long retain its virtue, particularly if it hangs looſe ſo as it can turn north and ſouth.—Lay four ſmall bars of ſteel touching one another in a line, lengthwiſe ; ſlide one pole of a magnet from the right hand to the left over them ſeveral times, and they will be good magnets: But if then you ſlide the ſame pole over them from the left hand to the right, the magnetic virtue will be entirely taken from them. *Fire* and *ruſt* deſtroy the power of theſe magnets, and time will weaken them, if a conductor of iron or ſteel do not form a magnetic circuit for the effluvium to paſs through. To recal the decreaſed virtue of a magnet, hang a large *ſand-bag* to the iron adhering to it, and keep every day increaſing the ſand.—To give the virtue to a *knife*, draw it over either pole from hilt to point ſeveral times.

By fire, is underſtood a complex idea of ſomething *red, ſhining, that excites the ſenſation of heat, and rarefies or expands all known bodies.* It is the moſt powerful agent in the decompoſition of bodies. It is the only *eſſential fluid* in nature, and the cauſe of fluidity in other bodies, by ſeparating their parts ; hence, even air itſelf may become ſolid when deprived of the fire it contains, as bodies of the moſt difficult fuſion become fluid when penetrated by a ſufficient quantity of the particles of fire. *All* bodies become hot by the approach of ignited bodies, and by friction ; but bodies that contain a ſufficient quantity of phlogiſton, *only*, are capable of inflammation. Phlogiſton is not fire, but one of the principles of inflammability ; *i. e.* when it is combined with various ſubſtances in due proportion, it renders them inflammable with air ; Phlogiſton may be ſeparated from one body, and given to another ; hence an inflammable body may be deprived of its inflammability, and a body naturally not inflammable, may be rendered ſo by combining it with a ſufficient quantity of phlogiſton. When expelled from bodies it is not annihilated—it only eſcapes from the burning body into air, which gives proof of

its having acquired it, and is then faid to be *phlogifti-cated*; and hence no inflammation will take place but in the common air. Combuftion ceafes when the air furrounding the burning body is filled with phlogifton—hence a fire is put out by blowing phlogifticated air into it —but enlivened by a current of frefh air. All bodies contain more or lefs of this wonderful principle—for all bodies grow hot by violent friction; friction may be therefore faid to be a kind of *fire-pump*, that draws latent fire from the adjoining bodies to the place where the friction is going on, and ftrongly indicates that phlogifton may lie in a concrete form in, and be a conftituent part of all bodies; nay, *Birgman* fays, 100 ounces of charcoal contains 99 ounces of phlogifton, and but one of earth; metals deprived of their phlogifton are heavier as a calcs than as a metal; inflammable air is eight or ten times lighter than common air, &c. So little do we know of fire, that any attempt at a theory of it muft appear prefumptuous and premature; we find however that *light*, *heat* and *electric fluid*, have fo many qualities in common with *phlogifton*, that hereafter it may probably be found they are all but modifications of the fame principle. Rubbing, or friction, in *all* bodies produce *heat* and *electricity*, and both thefe dilate bodies, help vegetation, germination, evaporation, motion of the blood, the growth of the fetus, and the hatching of eggs. Heat and electricity both reduce, and melt metals; and bodies that receive *heat* with difficulty receive *electricity* fo, &c. May not the rays of the fun be diluted phlogifton? May not the velocity with which they proceed from the fun prevent their abforption by the air, in their paffage through it? And as all bodies have more or lefs affinity to phlogifton, may not this diluted phlogifton be abforbed by various bodies, and lie in a concrete form in them till called forth from them by friction or combuftion? Experiments that favour this hypothefis are, 1ft. Rays collected in the focus of a burning glafs, produce on opaque bodies the moft intenfe heat that is producible by the art of man. 2d. Living vegetables imbibe phlogifton (as nutrition) from the air,

and part with it back again into the air in the act of combuftion, boiling, or putrefaction ; (for rotten wood, putrid fifh, ignis fatui; indeed, all animal and vegetable fubftances are luminous while decompounding by putrefaction)——which is but parting with the *inflammable principle* that was a conftituent part of thefe bodies while in health. 3d. Bodies in the act of *delivering* phlogifton to the air, or any other affinitive menftruum are *univerfally hot* ;——hence the heat of a common fire, where phlogifton is transferring from the coals to the air ; inflamed gunpowder, &c.——The *heat* of effervefcent mixtures, fuch as diluted vitriolic acid, and iron filings :——Copper and diluted nitrous acid :——Iron filings, water, and fulphur :——Air carrying off phlogifton from the lungs in the act of refpiration, and thereby producing animal heat : Pyrites and water producing the heat of the Bath waters, &c. which is but the water feizing the vitriolic acid, and thereby expelling the phlogifton of the acid into the air, for a mixture of vitriolic acid and water always produce an intenfe heat :——The production of fire by the efcape of phlogifton from phofphorus, pyrophorus, &c. when expofed to the air is another inftance :—and the aftonifhing flame arifing from oil of turpentine when a mixture of vitriolic and nitrous acid is poured upon it, alarms, while it proves, that air is the natural menftruum of phlogifton, and that inflammation will not take place except in common air. 4th. A fire-brand expofed in dephlogifticated air blazes out with a vivid flame, while the air feizes its phlogifton. 5th. Metals calcine but partially in fmall quantities of confined air, that air is fo foon faturated with phlogifton ;——a current of air muft pafs over melting metals or they will not calcine :——Air fo expofed becomes phlogifticated and diminifhed. 6th. Metals reduced to a calcs by calcination, or by a folution in acids, part with their phlogifton during the procefs ; and a calcs expofed in inflammable air, and heated by the focus of a burning lens, imbibes or fwallows up the inflammable air, and revives into a perfect metal!——This extraordinary fact fhews, that metals may as it were be taken in pieces and put together again——for if the phlo-

giſton that flies off from a calcining metal could be preſerved, and the calcs of that metal be heated in it, the calcs would ſeize the phlogiſton it had loſt, and become the very ſame metal it was before the proceſs. Hence we have reaſon to believe that inflammable air is the true *elementary phlogiſton*, and that it is this gas in a concrete ſtate in coals, candles, wood, metals, &c. that makes them inflammable. Phlogiſton in an active ſtate produces *heat*——approaching to a latent ſtate, *cold.* Hence the evaporation of volatile ſpirits; the mixture of ſalt and ſnow—and ſnow and ſpirit of nitre, ſerve to concentrate or deaden the action of phlogiſton,—and by theſe mixtures in cold weather and cold climates, quickſilver has been frozen into a ſolid metal.

LECTURE II.

MECHANICS.

THE *attraction of gravitation* is the weight of bodies, or that tendency which matter has towards the centre: By this power the earth is formed into a denſe ball, and every thing that lives upon it held faſt to its ſurface. A body left to the power of this agent falls about a rood in the firſt ſecond of time; three roods in the ſecond ſecond; five in the third; ſeven in the fourth, &c. agreeable to the odd numbers, 1, 3, 5, 7, 9, 11, 13, &c. For the *vis inertiæ* of the falling body, added to the power of gravity in every ſucceeding ſecond, accelerates it, as the ſquares of the times. Thus,—at the end of the 4th ſecond the body has fallen about 16 roods,—at the end of the 6th ſecond it has deſcended 36 roods, &c. This is proved by a projected ball falling from an horizontal line one inch in the ſame time in which in falls 3, 5, 7, &c. inches in the ſucceeding times; and by the ſuſpenſion of unequal weights over a pulley. Hence we find this power of gravity decreaſes as the ſquares of the diſtances increaſe, (*i. e.* a ball, which weighs 9 lb. on the earth's ſurface, would weigh only 1 lb. at three ſemi-diameters of the earth above it.) For it is found that the moon falls from a tangent to her orbit in this proportion; ſhewing that ſhe is actuated by the ſame law that makes a pebble deſcribe a curve when it is thrown from a ſling. For that pebble, if it was projected with proper force, and had a vacuum to move through, as the moon has, would go round the earth for ever as ſhe does.

Motion is rectilineal; *i. e.* all bodies put in motion by *one* force, endeavour to go off in a ſtraight line. Hence,

if a coach in fwift motion be turned fuddenly, it overfets by endeavouring to go off ftraight: But if a body be impreffed by *two* forces, in oblique directions, it will obey neither, but go the diagonal of the fquare. Hence a ball dropt from the maft head of a fhip, under fwift fail, falls on the deck as if the fhip was at anchor: And a ball fhot horizontally from a tall tower, obeys neither the powder nor its own weight, but comes to the ground in a curve formed of the two. We fhall in due time fee that the planets move by this wonderful law.

The momentum of a falling body is as the fquare root of its height. Ex. Hang a pound weight on one end of a fcale-beam, and if at the other end you let fall a certain weight from the height of one foot, it will juft lift, or cant the pound up: But if you let the fame weight fall four feet, on one end of the fcale-beam, it will cant up two pounds weight hung at the other. If it falls nine feet, it will lift up three pounds weight at the other, &c.

Fluids fpout by the fame law. A pipe of the fame bore as another, but four times as far below the furface of the water in a ciftern, difcharges twice as much as the upper one; if it be fixteen times as far beneath the furface, it will difcharge four times as much as the upper one, &c. For the velocity with which a fluid fpouts, at any depth below the furface, is equal to that which a body let fall *that height* would aquire.

The *momentum*, or force, of a body, arifes from its quantity of matter being multiplied into the velocity with which it moves: Thus, if a *battering ram* be 1000 lb. weight, and the velocity with which it ftrikes a wall be 20, then is its *momentum* 20,000: But a cannon ball fhall do the fame execution, if its quantity of matter be no more than 10lb. provided it be thrown with a velocity equal to 2000, for $10 \times 2000 = 20{,}000$, fo that the *momentum* of both are equal. This may eafily be proved, by laying 2 lb. weight upon a *fpring*; if it throws it one yard, it will throw 1 lb. two yards; and 8 lb. will be counter-

poifed by 4lb. if it be hung on a balance at *twice* the diftance from the fulcrum. Hence the force, or power, of any machine, whether fimple or compound, is eafily computed; for when two bodies are fufpended upon any machine, fo as to act againft one another, if the perpendicular *afcent* of one body, be to the perpendicular *defcent* of the other in the inverfe ratio of their weights, they will balance one another; and therefore fo much quicker as the power moves than the weight, fo much is the advantage gained by the machine, and gives this mechanical anxiom, " That what is gained in power, by any machine, is loft in time of working it. Sir *Ifaac Newton's*.

All kinds of mechanical engines confift, more or lefs, of thefe *fix powers*, viz. the *lever*, the *wheel* and *axle*, the *fyftem of pulleys*, the *inclined plane*, the *wedge*, and the *fcrew*.

The *lever* is a bar of wood, or metal, turning upon a prop, or centre, (commonly called the *fulcrum*) and is ufed either to raife weights or overcome refiftances. There are three kinds of levers, and in each of them, the velocity of each point is directly as its diftance from the prop. When this *prop* is between the *weight* and the *power*, 'tis called a *lever of the firft kind*. and fo much as the power is further from the prop than the weight, (or its center of gravity) fo much is the advantage gained by the power over the weight. *Iron crows, fciffars, pincers, rudders of fhips, &c.* are *levers of the firft kind. A lever of the fecond kind*, is when the *weight*, or *refiftance*, is between the *prop* and the *power*, as in doors turning on hinges, knives that turn on a centre at the point; oars, *&c. A lever of the third kind*, is when the *power* is applied between the *weight* and the *prop*, as in rearing a ladder againft a wall; moving our legs and arms by the power of the mufcles, &c. The *bended lever* differs in nothing from one of the *firft kind*, but in form, it is like a hammer drawing a nail. In each of thefe levers, fo much as the *power* moves farther, or fhorter than the weight, fo is

the advantage, or difadvantage, of each. The power of a *compound lever* is found by multiplying the power of each into one another.

In the *wheel and axle*, the advantage of the *wheel* over the *axle*, is as their diameters, *i. e.* if the *wheel* be four times as large as the *axle*, a man may lift four times as much by it, as by his own ftrength, allowing for friction. This *power* is the principal part of a common *crane*.

Upper pulleys that are fixed, only ferve to change the direction of the power, and give no mechanical advantage thereto; but the under block of pulleys, moving with the weight, give an advantage proportionate to the number of ropes by which the weight is fuftained; and which may be eftimated alfo by fo much as the power moves fafter than the weight. A *running pulley* doubles whatever advantage was gained by the other parts of a machine before it was applied, always allowing for friction, which in pulleys is very great.

The *wedge* feparates heavy, or cohering bodies, with a force proportioned, *as the thicknefs of its back is to the length*; *i. e.* if its back be one foot, and the length twelve feet; then may the momentum of the ftroke which moves the wedge be one twelfth only of the weight, or cohering force, of the parts to be feparated.

The *inclined plane* is half a wedge, and therefore its power is, *as its length is to its height*; *i. e.* I fhall roll a cylinder up an inclined road of twenty yards in length, and but one yard perpendicular height, with one twentieth part of the force that would be neceffary to lift it perpendicularly that yard.

The *fcrew* may be confidered as an inclined plane wrapt round a cylinder; therefore as the power moves round the cylinder, while the weight rifes, the power has an advantage over the weight, as the length of one thread round the cylinder, is to the diftance of one thread from

another; or as the velocity of the power is to the velocity of the weight.

In a *common jack* we have all thefe powers together, if to an arm of the fly the power be applied; and fo far as that power moves farther than the weight, fo much is the advantage which the power has over the weight.

If machines could be made to move without *friction*, the leaft degree of power added to that which balances the weight would be fufficient to raife it: But as the fmoothest bodies are full of pores, and little eminences, thefe will lock into one another in rubbing bodies, and greatly retard the motion of a machine. The friction in the *lever*, and in the *wheel* and *axle*, is very fmall: In *pulleys* it is very confiderable: But in the *inclined plane*, the *wedge*, and the *fcrew*, it is very great. The allowance made for friction in machines confifting of feveral of the mechanic powers, is ufually *one third*; *i. e.* after calculating all the fingle powers as above, and multiplying thefe into one another, from the laft product I deduct one third of it, and the remainder is the true momentum or force of the machine. Friction is of two kinds: The *rubbing friction*, and the *friction by contact*; the rubbing of the locked wheel of a coach againft the road may reprefent the *firft*; and the manner of its touching the road in its ufual motion the *fecond*. When the *firft* kind of friction can be reduced to the *fecond*, there is a manifeft advantage given to the power of the machine, as is demonftrated by the experiments with the friction wheels. Thefe wheels are hung fo that their peripheries form an angle, in which the gudgeon of the heavy wheel turns. *Water wheels*, large *grinding ftones*, and even *wheel carriages*, are hung in this way at a fmall expence; but being apt to wear out very faft, they are better fitted to fmall weights moving with great velocity. And hence the friction balls in wheel carriages, cranes, &c. become foon ufelefs. A *narrow* rubbing furface has much the advantage over a *broad* one, though they each fuftain the fame weight, becaufe of fewer points and pores being in contact;

hence the ſmaller the gudgeon or axle of a wheel the better, if it has but ſtrength to ſupport the weight. The friction in water that carries an under-ſhot mill, is much taken off by a ſloping pedal; the velocity of the flat-boards of the wheel ought to be one-third of the velocity of the water; the number of ſtaves in the trundle ought to be no even part of the number of cogs in the wheel that turns it; and the grinding ſtone ſhould not make above 60 revolutions in a minute.

Beſides the *mechanic powers*, and various inſtruments to explain *friction*, momentum, falling bodies, &c. the machines uſed to illuſtrate this lecture are, 1ſt. A moveable crane. 2d. A mill to ſaw marble. 3d. Ditto to ſaw timber. 4th. A common pile-driver. 5th. Voulou's pile-driver. 6th. The equitable moving wind-mill, that cloaths, uncloaths, and turns itſelf to the wind. 7th. Drill-ploughs. 8th. Ventilators. 9th. Wheel carriages. 10. Methods uſed in moving the great ſtone on which the ſtatue of Peter the Great is erected in Peterſburg. 11th. A compleat fortification. 12th. Boulton, Blakey, Smeaton's and the common fire or ſteam engines. 13th. Water engines of all denominations, viz. common pumps, forcing pumps, rope pumps, Archimedes's ſcrew pump; bucket-engines, machines for draining, embanking, &c. &c. &c. Theſe, and many more, from their ſize, cannot be removed from the Winter Lecture Room, now in George Street, Hanover Square.

LECTURE III.

PRINCIPLES *of* CHEMISTRY.

ALL bodies exiſting on the earth may be arranged under three heads, viz. the *animal*, *vegetable*, and *mineral* kingdoms. The firſt comprehends all bodies endowed with life and ſelf-motion. The ſecond, thoſe which have life only, the power of growing, and propagating their ſpecies. The third, all bodies deſtitute of life and ſelf-motion. Bodies are alſo conſidered as *ſimple* or *compound.*—Simple bodies are ſuch as cannot be reſolved into any thing more ſimple, ſuch as pure earth, pure water, &c. Compound bodies conſiſt of two or more of the primary elements, ſuch as an *animal body*, for earthy particles and various fluids form its compoſition. That branch of philoſophy which examines the properties of theſe bodies, by compounding or decompounding them, is called CHEMISTRY.—A branch ſo extenſive and important, that the ſuſtenance of life—the arts and ſciences—various manufactories—nay, even trade and commerce depend upon a continual *compoſition* and *decompoſition* of natural bodies.

SOLUTION is a property of *fluids*, whereby they imbibe (or incorporate themſelves with) *ſolids*, by ſeparating their parts.—The ſea is a ſolution of ſalt in freſh water. Ink is a ſolution of vitriol and galls in water. Diluted nitrous acid diſſolves copper; when the ebullition is over, the liquor will be a ſolution of copper. Diluted vitriolic acid in like manner gives a ſolution of iron. Quickſilver diſſolves lead, tin, &c. Gold diſſolved in aqua regia is a ſolution of gold, &c. and camphor in like manner is diſſolved in ſpirit of wine, &c.—Solutions in water, ſpirits,

acids, air, &c. are tranfparent—but mixtures are muddy or opaque.

DISTILLATION is the application of heat to feparate fluid and volatile parts from bodies; and to collect them in other veffels by means of cold. Heat expands all bodies, and puts their particles into a repulfive ftate; when this application becomes more powerful than the cohefion of the body, a decompofition takes place. Sea-water put in a retort, and expofed to the fire, the water foon rifes in the character of fteam—this fteam paffing through a cold pipe is condenfed, and brought back again into water, but frefh, and the falts being lefs volatile, remain at the bottom of the retort. Liquors that have gone through a ftate of vinous fermentation, are difpofed to part with fpirit—and fpirit rifing in fteam with lefs degree of heat than water, a feparation of the two is eafily effected in a ftill, by tempering the fire,—hence the fteam of the fpirit paffing through a long fpiral pipe (immerfed in cold water) is condenfed:—when the fpirit is all come over, the water begins to rife in fteam, and may be received in a feparate veffel—the earthy and colouring particles of the wine will at laft be found dry at the bottom of the ftill.

SUBLIMATION is but a diftillation of dry fubftances. *Sulphur* expofed in a fubliming veffel, is melted with a very gentle heat, and rifes in fteam, forming flours of fulphur on the fides and top of the veffel, and is but the fame fulphur that was melted. *Gum benzoin* melted within a tall receiver, with a fprig of rofemary in it, rifes and forms an hoar-froft appearance on the leaves of the rofemary.—*Phofphorus* juft covered with water, in a Florence flafk expofed over a lamp, fublimes into the appearance of ftars, and the aurora borealis. It rifes with the fteam of the water, and ftruggling to obtain the air, its menftruum, forms beautiful corufcations in the flafk, particularly when feparated from the lamp, and expofed in the dark.

PRECIPITATION is performed in fluid matters only—it is a disuniting of two or more ingredients by the addition of another, which by its greater affinity, unites with one of the ingredients, and separates the others from it, and by which they generally fall to the bottom of the liquor. Copper dissolved in diluted nitrous acid, is precipitated by iron—much of the dissolved copper becomes revived by the phlogiston of the iron, and forms a skin of copper on the iron; the rest falls to the bottom of the liquor precipitated, &c. &c.

SATURATION signifies the point at which the attractive and dissolving power of any menstruum stops, when filled with the matter it is to dissolve.—Solutions of salt or sugar in water; of sulphur in oil of turpentine; camphor in spirit of wine; silver in aqua fortis; water in air, &c. are transparent till fully saturated; if more be added, they sink, in their natural form, to the bottom undissolved, and the menstruum is said to be fully saturated. If water, spirits, oil, &c. be evaporated from the matter with which they are saturated, the matter assumes its natural form;—common salt will assume a cubical form; salt-petre the form of a prism, &c. &c. adhering to the bottom and sides of the containing vessels.

AFFINITY. This term is of great extent in chemistry, and signifies *the tendency which the constituent parts of bodies have to unite readily with* SOME *substances in preference to others.* Water and vinegar have affinity, because they are easily mixed together. Water and oil have no affinity because they will not mix, but shew a kind of repulsion to one another. If a mixture, A and B, have a third matter, C, added to them, to which A has a greater attraction or affinity than to B, then will A let go B, and join in union with C, and B is precipitated, Ex. 1st. Solution of sublimate mixt with oil of tartar. produces an orange coagulum; an acid (as the spirit of nitre) added, seizes the oil of tartar, (as an alkali, to which it has a strong affinity) the colour is discharged, and the liquor becomes pelucid. 2nd. A Solution of blue

vitriol mixt with ſpirit of ſal-ammoniac, produces a blue-coloured alkaline liquor. The nitrous acid, added, ſeizes the ſal-ammoniac as an alkali, diſcharges the colour, and the liquor becomes acid; if then an alkali be made predominant (as oil of tartar) the fine blue is again reſtored. 3d. Acid ſolutions are detected by ſyrup of violets, which turns them red: but the ſame ſyrup turns an alkaline ſolution green. Hence red or blue flowers ſteeped in acid water, impart their colouring particles to the water, which becomes red: oil of tartar added, turns it green. 4th. Salts inſtantaneouſly chryſtalize when ſpirit of wine is added to their ſolution in water,—becauſe ſpirit and water have a greater affinity to one another than ſalt and water. 5th Inflammable air is not inflammable of itſelf, any more than fixt air is effervefcent; but it is a conſtituent part of a compound, which being let looſe, cauſes by its mixture with the empyreal part of the atmoſphere the phænomenon of inflammation. Hence phoſphorus (as a mine of phlogiſton) when rubbed between the folds of brown paper to increaſe its ſurface and give it a little warmth, takes fire ſo ſoon as it becomes opened out to the air. 6th. Two thirds of nitrous acid and one third vitriolic acid mixed, and then poured on oil of turpentine, produces inſtant and tremendous inflammation! 7th. Ether dropt on water produces ice. 8th. Calcs's are revived, if while they are in fuſion, inflammable air be blown upon them, 9th. Equal quantities of regulus of cobalt diſſolved in diluted nitrous acid, and ſea ſalt diſſolved in water, make an ink that comes and goes with heat and moiſture. 10th. Inviſible writing, with a ſolution of ſugar of lead, is rendered black by a ſolution of liver of ſulphur, both in water. This phlogiſtic effect will take place through a thick book, or even a ſtone wall. 11th. Hembergs's pyrophorus requires one part ſugar and three parts allum, to be melted, ſtirred, and dried on an iron ſhovel till it becomes a blackiſh coal; then bruiſe it into powder, and put it into a long-necked bottle, and the bottle into a crucible filled with dry ſand; then place the crucible in a grudual fire, till the whole becomes red hot, and keep it ſo an hour, or till a weak ſulphureous flame

has iſſued out of the bottle's neck a quarter of an hour; remove it by degrees, and cork up the bottle as ſoon as it will not burn it, or decant the pyrophorus into a dry bottle, well ſtopped from air. A little of this powder expoſed to moiſt air on brown paper, inſtantly takes fire. 12th. Vitriolic acid contains more latent fire than water by one-third—therefore, when mixt, an equilibrium takes place, and the three parts are let looſe in ſenſible heat. Hence iron pyrites lying in water produces heat, and becomes ink with an infuſion of galls; rain water running over quarries of ſuch pyrites above Bath, acquire the heat for which thoſe waters are celebrated. 13th. Vegetables contain much nitre; the water therefore in which potatoes, ſpinage, &c. are boiled diſſolves the nitre, and hence brown paper ſoaked in ſuch water, becomes excellent *match* when cut in ſlips and dried. 14th. Silver diſſolved in diluted nitrous acid, (or luna cornea) is precipitated by copper; for the acid has a greater affinity to copper than ſilver, therefore the ſilver precipitates, and form thoſe beautiful ramifications called the arbor Diana.

ACIDS are both in a liquid and concrete form, have a ſour taſte, and they effervеſce with alkalies. *Vitriolic acid* is fluid, tranſparent, colourleſs, and without ſmell; like water, but much heavier. It is got generally from ſulphur, by diſtillation with water, to which it has great affinity.——*Nitrous acid* is of a brown colour, emits brown vapours, has a pungent ſmell, readily diſſolves moſt metals, and is extracted by diſtillation from nitre or ſalt-petre, moiſtened with vitriolic acid. It attacks the phlogiſton of metals, and has the greateſt affinity to it. *Marine acid* is extracted from common ſalt, it is of a yellow colour, and ſmells like ſaffron.

ALKALIES, are ſaline bodies that combine readily with acids; in a concrete form they attract moiſture from the air, and become fluid: they have an acrid burning taſte; fuſe with a moderate heat; diſſolving earths with a ſtrong heat; become glaſs, &c. *Fixt mineral alkali* is obtained from ſea ſalt; *fixt vegetable alkali* from

vegetables, both ſtanding a great heat without diſſipation. *Volatile alkali* is obtained from animal ſubſtances, by decompoſition and putrefaction, and flies off with a *ſmall* degree of heat; hartſhorn drops are of this kind. Alkaline ſalts combined with oils form ſoap, &c.

SALTS are every thing with a ſharp taſte, and ſoluble in water. *Sea ſalt*, or *kitchen ſalt*, is a combination of marine acid and mineral alkali. *Luna cornea* is a ſalt formed by the union of ſilver and acid. *Verdigriſe*, ſalts formed by the ſolution of copper in vinegar. *Ammoniacal ſalts*, are an acid ſaturated with volatile alkali. *Sugar*, an eſſential ſalt, containing vegetable acid combined with earth and oil. *Potaſh*, a fixt vegetable alkali extracted from the aſhes of vegetables. *Nitrous ſalts* are found in old walls, or places impregnated with animal and vegetable juices——they are neutral, and produce nitrous acid and fixt vegetable alkali.

METALS. *Perfect metals*, or thoſe that cannot be decompounded, are, gold, platina, and ſilver. *Imperfect metals*, are, copper, iron, tin, and lead, which in fire or ſtrong menſtruums loſe their metalline properties become an earth, or calcs; but are revivable back to their original metals by phlogiſton; hence imperfect metals are wholly compoſed of earthy matters and phlogiſton. Pure metals are always found in their metallic form; but the imperfect metals in the form of calcs's or ores; theſe placed in a ſtrong fire acquire from the combuſtibles phlogiſton enough to become metals, and are then combuſtible themſelves in a ſtrong fire: Sparks produced by the ſtroke of flint and ſteel, are but particles of ſteel ſet on fire by the violence of the ſtroke. *Gold* is unalterable by art, is the heavieſt of all known bodies, expands ſo, that a grain may be beat into a leaf of fifty ſquare inches, and a gold wire one tenth of an inch in diameter, will ſuſpend or ſupport 500lb. weight without breaking. Reduced into fine powder, it is eaſily attacked by acids, but its metallic nature is in no reſpect altered. Gold diſſolved by aqua regia, and then precipitated by volatile

alkali, and then waſhed and ſuffered to dry, explodes by a ſmall degree of heat, with a quickneſs and violence far exceeding gunpowder. Ether poured on a ſolution of gold in aqua regia, and the mixture ſhook—the gold will leave the aqua regia and paſs into the ether. Gold will continue months in a hot fire without loſing any weight. *Platina.* This metal is found in ſmall, angular, ſhining grains in the gold mines of South America; it is near as heavy as gold naturally, but deprived of the iron with which it is generally united it is heavier. It diſſolves in aqua regia, but bids defiance to ſimple acids, or any fire, except that of a large burning glaſs. *Silver* is the third unalterable metal—it fuſes in a ſmall heat; is nearly as ductile as gold; a wire of it one tenth of an inch diameter will ſuſtain 270lb. It aſſumes a black appearance when expoſed to phlogiſtic vapours, for it is capable of over ſaturing itſelf with the inflammable principle. Nitrous acid diſſolves ſilver more compleatly than any other acid. *Copper*, though an imperfect metal, comes near to ſilver in point of ductility. A wire, as above, ſupports 299lb. Moiſt air tarniſhes, and even calcines it; this ruſt, or calx, is verdigriſe. Acids, alkalies, ſaline matters, and oils, more or leſs diſſolve copper, and the ſolution is of a green colour, and poiſonous; hence culinary veſſels of copper ſhould be kept well tinned. A ſolution of copper in volatile alkali is blue when expoſed to the air, but loſes the colour when corked up; opened. it again becomes blue, &c.—So water impregnated with too little copper to be diſcovered, turns blue with a few drops of volatile alkali. Copper is moſtly found combined with ſulphur in mines; and is eaſily ſeparated from other metals by ſulphur. It requires a ſtrong heat to melt it, emits pernicious fumes, and burns with a green or blue flame. It eaſily combines with other metallic ſubſtances—with zink it becomes *braſs*—with tin, *bronze*, or *bell-metal*, &c. *Iron* is the moſt uſeful, the hardeſt, moſt elaſtic, and, except tin, the lighteſt of all metals. Such a wire as above, ſupports 450lb. As an ore, or a calx, it is not attracted by the magnet—but when phlogiſticated by roaſting in the fire, it is attracted. It is eaſily

deprived of phlogiſton, by the calcs of other metals, water, moiſt air, acids, fire, &c. and becomes ruſt, or *crocus martis*. Iron, joined by ſubſtances that abound with phlogiſton, in a ſtrong fire, without the free acceſs of air, becomes *ſteel*; and ſteel made red hot, and ſuddenly cooled in water or oil, becomes ſo hard tempered, and brittle that edge-tools, files, &c. are made of it. In the act of heating it changes colour, and hence many ſteel ornaments are made blue. Iron has great affinity with ſulphur, and its fuſion is ſo much facilitated by it that if iron in white heat, be rubbed with ſulphur, it falls in liquid drops united with the ſulphur; and if 60lb. of iron filings and ſulphur, made into a paſte with water, be buried a few inches under ground, it will ſwell, grow hot, emit vapours and flame, and ſhake the ground about it like an earth-quake. Iron may be allayed with any metal except quickſilver and lead. *Tin* is the lighteſt, leaſt elaſtic, or ſonorous of any metal. A wire as above, ſupports 50lb. All acids diſſolve and deprive it of its phlogiſton. It melts with leſs heat than will make it red hot, and calcines into a grey powder called putty, (uſed in poliſhing metals, glaſs, &c.) It allays with all metals, gives them brittleneſs; and its vapours impair the ductility of all metals. It amalgamates with quickſilver, and is then uſed to cover looking-glaſſes; compounded with lead it forms the ſolder of the plumbers.—*Lead* is ſtill ſofter than tin; a wire as above only ſuſtains 29lb. Acids of all ſorts diſſolve it—fumes of vinegar ruſts it into *white-lead*. Calcs of lead is made into wafers; boiled in linſeed oil, it becomes the *drying-oil* of the painters. Lead kept in a ſtate of fuſion, with a current of air paſſing over it, ſoon loſes its phlogiſton, and becomes calcined, and is then called *red-lead*: a ſtronger heat vitrifies this calx into *litharge*: and a ſtill ſtronger heat, reduces it into *glaſs of lead*, which will run through the crucible like water through a ſieve. This glaſs facilitates the calcination of imperfect metals, and is therefore uſed to purify the *perfect* metals. *Mercury*, or *quickſilver*, is like fluid ſilver opa-

que and very heavy. By great cold it can be made ſolid, and malleable as lead. It riſes in vapours by a ſmall degree of heat, and when theſe vapours are collected, they are found the very ſame quickſilver. Hence it is eaſily diſtilled, and by that means eaſily ſeparated from lead, tin, &c. Acids and alkalies combine with mercury. Vapours of mercury and marine acid meeting, form chryſtals like flattened needles, called *corroſive ſublimate.* Mercury ſhook in vinegar, exhibits a curious phænomenon; and it is luminous when ſhook in vacuo. Quickſilver triturated with ſulphur, forms *Ethiops mineral*; and this frequently ſublimed, becomes cinnabar— or the vermilion of the painters. Cinnabar is alſo found a native in the mines, and may be conſidered as the ore of quickſilver.

E A R T H S.

Earths make up the ſolid part of our globe; they are ſo intermixed, that it is difficult to come at their components, which are, 1ſt. *Calcareous earths, i e.* lime-ſtone, chalk, ſtalactites, or ſtone icicles, marbles, or any earths that effervefce with acids; that fall in white powder when burnt; that will not melt into glaſs by heat; but will melt when mixed with borax, or calcs's, and aſſiſt the fuſion of lead, copper, and iron. *Siliceous earths*, or precious ſtones, as the diamond, ruby, topaz, opal, agate, cornelian, flint, jaſper. Many of theſe ſtrike fire with, and even ſcratch ſteel;—do not melt with the ſtrongeſt fire; and do not effervefce with acids. *Argillaceous earths*, or clays that harden in the fire, and uſed to make porcelain; and clay marles, that moulder in water, and effervefce with acids, uſed as manure. *Micaceous earths* are compoſed of thin leaves, or lamina, with ſhining ſur-

faces, and which divide into thinner leaves in the fire, and become brittle. *Asbestus earths.* These do not alter in the fire; are flexible and stringy, capable of being spun into threads, or wove into cloth. *Zeolites* are harder than calcareous stones; melt easily in the fire with swelling and ebullition; and dissolve with acids without effervescence.

LECTURE IV.

PNEUMATICS.

THE air is a thin fluid, which encompaffes the globe of the earth on all fides, revolves along with it round its axis, and attends it on its annual journey round the fun. If a peach be fuppofed to reprefent the earth, the air will be aptly fignified by the down growing on its furface.

This body of air, (together with the clouds and vapours that float in it) is called the atmofphere; and it reaches about forty-five miles above the ground before it degenerates into too thin an æther to refract the rays of light, or for any creature to breathe; this is known by meafuring with a barometer the weight of the atmofphere in a low valley, and on a mountain, and may be familiarized by fuppofing a thoufand fleeces of wool one piled above another, where the loweft will be greatly compreffed or fqueezed together, the next not fo much, the next not fo much as that, &c. till we come to the uppermoft, which will lie in its natural loofe ftate. The air, by being elaftic, and partaking of the earth's attraction, is neceffarily drawn into progreffive ftate like this.

The air is fo fubtil that it pervades the pores of all bodies, and enters into the compofition of moft animal and vegetable fubftances; yet it is a body, becaufe it excludes all other bodies from the place it poffeffes, if fo confined that it cannot efcape; hence the origin of the diver's bell, for if we fink a bell in water with the mouth open downwards, little water will make its way into it, and a perfon may defcend and live at a confiderable depth, if a veffel of the fame kind be kept conftantly

ſupplying him with freſh air, and that made noxious by his breathing be let out by a pipe reaching from the upper part of the bell above the ſurface of the water. For air taken into the lungs, returns phlogiſticated, having brought off the ſuperabundant phlogiſton of the blood, which makes a digreſſion from the heart to receive purification from the air; and hence the blood returns thin, florid, and fit for circulation, while the expired air is ejected into the general maſs phlogiſticated and unwholeſome.

The air has all the properties by which a fluid is diſtinguiſhed, it yields to the ſlighteſt impreſſion, its parts move eaſily among one another, and animals breathe and move through it without any difficulty. Yet it has three ſingularities which diſtinguiſh it from moſt fluids. 1. It can be compreſſed into a leſs ſpace than it naturally poſſeſſes. 2. It can occupy a greater ſpace than it naturally poſſeſſes. 3. It is of different denſity in every part upward.

As the air is a body, it muſt needs have *weight*; this is proved, 1. By its preſſing the hand that covers the top of an exhauſted receiver. 2. By immerſing the ſtem of a bolt-head into a veſſel of water, and covering both with a receiver, then exhauſting the air out of both; on letting in the air on the ſurface of the water it forces it into the exhauſted bolt-head. 3. A bottle that holds a wine quart being emptied of air, and weighed, is found to be about 17 grains lighter than when it is full of air; ſo that a quart of air on the earth's ſurface is 17 grains. 4. If a wet bladder be tied over the top of an open receiver, then ſet to dry, and after this the air exhauſted from under it, the air's weight will then burſt the bladder with a ſurprizing report. 5. On a moveable plate place a tall receiver, open its cock, and exhauſt the air out of it, then ſhut the cock, and immerſe the ſtem in which it is fixed into a veſſel full of water; on opening the cock the air's preſſure on the water will force it into the receiver in a beau-

tiful fountain. 6. If a hole be made in the bottom of a cup, and have a bit of dry hazel or willow branch fixed into it, and this be put into a hole on the top of a receiver; when quickſilver is poured into it, and the air exhauſted, the quickſilver will be forced thro' the pores of the branch by the weight of the incumbent air, and will fall in a curious ſhower into the receiver. 7. If a tube of 32 inches long, and open only at one end, be filled with quickſilver, and then the open end immerſed in a jar of quickſilver, *that* in the tube will ſink to the height the quickſilver ſtands in the barometer; if this jar and tube be put under a tall receiver, and the air exhauſted, the quickſilver will deſcend out of the tube into the jar; but upon admitting the air again into the receiver, its preſſure will drive up the quickſilver into the tube, and ſupport it therein as it ſtands in the barometer, which proves that the quickſilver in the barometer is kept up ſolely by the weight of the air. 8. If the air be exhauſted out of two braſs hemiſpheres of about 12 inches area, it will require a force equal to 180 pounds to ſeparate them.

To prove that theſe effects are not produced by *ſuction*, and that there is *no ſuch principle in nature*, 1. Place a ſmall receiver at ſome diſtance from the hole in the pump-plate, and cover it with a large one *over* the hole; on exhauſting the air the ſmall one will remain looſe, while the large one is made faſt to the plate; but on letting in the air the big receiver will be releaſed, and the ſmall one preſſed down. 2. If a pump be placed in water under a receiver, and the air exhauſted, no water can be made to riſe in the pump. 3. If two moveable plates be fixed upon a pump-plate, with communications between them that can be ſtopped by cocks, if the air is exhauſted out of a receiver placed on one of them, and then a receiver placed on the other, and the communication opened, half the air in the laſt will by its ſpring make its way into the firſt receiver, and both ſhall be fixed on the plates.

Breathing is in fome meafure performed by the power of the intercoftal mufcles acting upon the ribs; they are difpofed in form of a femicircular arch, and articulated with the vertebræ of the back behind, and connected with the fternum before, which are the two center on which they move: The diaphragma is a partition drawn acrofs the body, dividing the thorax or cheft from the abdomen or belly; it is a mufcle, and by its difpofition and ftructure capable of expanfion, whereby it becomes concave downward, and of contraction, whereby it becomes flat; and by this motion alternately rarefying and condenfing the air in the crevices of the thorax, aud thereby deftroying its equilibrium; to reftore this the air will prefs into the lungs, and when the diaphragma contracts, will be forced out again; hence the action of breathing, as is reprefented by the lungs-bladder, whofe infide has a communication with the external air, though it is inclofed in a thorax of glafs with its bottom clofed by a bladder, tied flaccid, reprefenting the diaphragma.

The *elaftic quality*, or *fpring*, of the air is thus proved, 1. If an almoft empty bladder be put under a receiver, and the air exhaufted, the fpring of the air in the bladder will then fhew itfelf by fwelling up the bladder, as if it was blown. 2. If a little of the fhell be cut off from the fmall end of an egg, and the egg put under a receiver, on exhaufting, the bubble of air in the big end of the egg will expand itfelf, and drive out the contents of the egg. 3. If a fifh in water be put under a receiver, and the air exhaufted, its air-bladder will fwell the fifh fo as to make it fpecifically lighter than water, and of courfe the fifh will be buoyed up to the furface. 4. If a cubic inch of dry wood in warm water be put under the receiver, aud the air exhaufted, large and innumerable bubbles of air will come out of the wood and make the water feem to boil; and in this manner may air be drawn vifibly out of the hardeft bodies. 5. A withered apple in an exhaufted receiver will be plumped

up, and look quite frefh, by the fpring of the air in the infide of it; and if a frefh one be pricked all over with a bodkin, and put in water under a receiver, on exhaufting, it will appear as if it was roafting by a fire. 6. If a tall receiver be exhaufted, and the neck of the veffel joined to its bottom be half full of water, the fpring of the air on the furface of that water will force it out into the receiver in a beautiful fountain. 7. If a little air be tied up in a bladder, and put in a convenient veffel with great weights upon it, on exhaufting the air, the fpring of the air in the bladder will lift the weights, and fhew that its fpring is equally forcible with its preffure; therefore, though a middle-fized man fuftains above 30,000lb. weight on his perfon, yet the equal fpring of air within him makes him infenfible of it.

Heat and cold, or, if you will, the prefence or the abfence of fire, are the ufual caufes of the air's rarefaction and condenfation: If *air* be heated, it fwells, fo that the fpace it poffeffed before it was heated will contain fewer particles than it did in its cold ftate. *Wind* muft be the neceffary confequence of this; for by what means foever the equilibrium of the air is deftroyed, its neighbouring parts will never be at reft till the balance is reftored: Hence the reafon why air rufhes fo violently into a glafs-houfe; into a clofe room with a great fire in it; into warm towns, &c. When the fun's heat is increafed by the reflection of fands, or the fides of rocky mountains, &c. the air will be rarefied, and by the rufhing in of the colder neighbouring air will be forced up into the higher part of the atmofphere, as light fmoke is up a chimney by the heavier air. If a large cloud keeps the fun's rays from the *air* under it, but rarefies *that* all round it, a wind will rufh from beneath the cloud in all directions. Upon this principle alfo we account for the *trade winds* which conftantly blow from the eaft towards the weft about the equator; for as the fun paffes over the earth in that direction, and rarefies the air as he goes, by heating the earth, and bottom of the fea (for tranfparent bodies receive no heat from folar rays) the colder

air will rufh after him. This effect is alfo increafed by the greater centrifugal motion, which the equatorial parts of the globe have more than thofe parts nearer the poles; by which the globe flides as it were from under the air, caufing an apparent motion in it the contrary way to that on which the earth turns on its axis——Hence alfo the *monfoons*; the *day* and *night* breeze, on the iflands in the Weft-Indies; the wind from weft to eaft on the coaft of Guinea; and the currents of Florida, Gibraltar, &c.

'Tis unneceffary to point out here how admirably thefe properties coincide with the general fcheme of the creation.

LECTURE V.

PNEUMATICS.

THAT the air may be condenfed or fqueezed into lefs room than it naturally poffeffes is proved, 1. By putting a blown bladder in a receiver; if a forcing fyringe be then applied to the receiver, and a quantity of air forced into it, the bladder will be fhrivel'd up by the fuperior preffure of the condenfed air. 2. If a copper ball be half filled with water, and a quantity of air forced into it as above, through a fpouting pipe that reaches nearly to the bottom of the water, the fpring of the condenfed air on the furface of the water will exhibit an amazing fountain. 3. The moft formidable inftance of condenfion is in the magazine, and walking-cane wind-guns; where the condenfed air has a fpring capable of difcharging 20 or 30 balls with one charge, one after another, with the fame force as if charged with gunpowder. Air fo fqueezed has a portion of its latent heat forced out, and the containing veffel becomes hot, like hammered iron.

By compounding charcoal and nitre, the principles of inflammation are united; charcoal affording phlogifton, nitre empyreal air, and fulphur fudden heat, by ignition. Hence flame difplacing the air around it, caufeth an explofion, which does not take place in vacuo.

Sound is caufed by any thing that gives a fmart ftroke or a tremulous motion to the air; thefe waves ftriking upon the outward fhell of the ear, are from thence conveyed up the auditory tube, and ftriking againft the tympanum, or drum, are fo increafed, that in making their way up the labyrinth, it gives a fhock to the auditory nerves, and, by their means, is conveyed to the foul the

idea of hearing, or ſound. The artificial ear makes this very evident. And the clock ſtriking in vacuo without being heard, is a proof of air being a conductor of ſound. Muſical ſtrings, in tenſion, ſtruck by a bow, a finger, the wind, &c. will divide themſelves into imaginary frets, or bridges. viz. into halves, thirds, fourths, &c. a bridge, either real or imaginary, dividing a ſtring into *two* equal lengths, each (*vibrating according to their weight*) will be an *octave* to the whole ſtring, as half will vibrate twice as faſt as the whole; and hence every ſecond wave unites with the firſt of the whole ſtring, and gives a pleaſing ſenſation to the ear.—A ſtring divided into *three equal parts*, each will vibrate three times while the whole ſtring vibrates once; hence every third wave coming in contact produces a pleaſing ſenſation, and the chord is called a *Twelfth*. Two-thirds of this ſtring vibrates *three times* while the whole ſtring vibrates *twice*, and gives that ſweet chord called a *Fifth*. *Seven-ninths* of a ſtring produce the major *Third*: and *three-fourths* the *Fourth*. Hence waves claſhing againſt one another without contact, produce *diſchords* in muſic, and ſerve as foils or reliefs to the counterpoint of according waves. Hence alſo the mechanical ſympathy of muſical inſtruments tuned in uniſon; one of which will ſound when the other does, by the waves it produces. An harpſichord replies to every word ſpoken in the room where it ſtands, when its ſtrings have no dampers upon them. Particular notes in an organ will ſhake the wainſcot, ſet dogs a howling. Hence alſo the various ſounds produced by the Eolian harp, when tuned uniſon, and expoſed to a current of wind——the ſtrings divide themſelves into imaginary bridges, and produce *octaves*, *fifths*, *thirds*, *twelfths*, *fifteenths*, &c. The maſterly performer on the violin aſſiſts this propenſity, by touching lightly thoſe aliquot parts of a ſtring where nature would make this imaginary bridge, and hence are produced thoſe notes called *harmonics*.

When the atmoſphere is light, the noxious air pent up in the cavities of mines (communicating with the out-

ward air) will, by its effort to reftore an equilibrium, fwell into the mine, and hence the fuffocating damp which is met with in mines when the barometer is low. This damp is made on the air pump by letting air into an exhaufted receiver, through the flame of charcoal, fulphur, flame of a candle, &c. into which if an animal be put it fuffers inftant death. The fire-damp proceeds from the fame caufe, only that its particles are of the phlogiftic or inflammable nature, as rifing from the fulphurous, nitrous, or oleaginous ftrata in the mine: This, taking fire by the lights ufed by the workmen, will run like a train of gunpowder through the works; and as it is confined, the elafticity occafioned by the heat will caufe fuch explofions as frequently blow up the mine. This damp is made on the pump, by letting the air into an exhaufted receiver through the flame of the oil of turpentine or other inflammable matters; after which, if a lighted candle be put in the vapour it will take fire.

As the pores and cavities of all bodies are filled with air, an animal put under a receiver, and the air exhaufted, will foon die; becaufe as the air is drawn out of the lungs, *that* in the thorax will expand and fwell the animal, fhrivel up its lungs, and thereby ftop the circulation of the blood.

Fixed air (*that wond'rous antifeeptic*) arifes from the effervefcence of any acid and alkaline mixture, and eafieft from chalk and diluted oil of vitriol.—Liquors fermenting difcharge plenty of it, and it is found alfo in the common atmofphere. It is a conftituent part of chalk, marble, limeftone, and all calcarious earth. Water imbibes it, and thence acquires the fparkling appearance, acidulous tafte, and medical qualities of *Pyrmont water*. Though noxious when breathed, it cures the fea fcurvy, putrid inteftines, inflamed, or putrid fores, &c. It is alfo faid to be a compound of phlogifton, and dephlogifticated air.

Nitrous air is produced from the effervefcence of copper filings and the nitrous acid.—It diminifhes common air,

in proportion to its purity: and their mixture produces a brown effervefcence.

Inflammable air, the pure and elementary phlogifton, is eafieft procured from iron filings and diluted vitriolic acid; the acid feizes the earth of iron, and lets loofe the fixt phlogifton, exhibiting it as *elaftic air.* This *gas* is imbibed by any metallic calx, in a ftrong heat, and the calx becomes revived into its original metal. Lead in calcining lofes its phlogifton——and becomes a calx called minium or red lead:——This phlogifton preferved, if the calx be placed in it, and the focus of a burning lens heat the calx, it inftantly begins to imbibe the inflammable air, fwallows it up, and foon becomes the individual lead it was before the procefs. This is taking a metal in pieces, and putting it together again; and intimates the *inflammable principle to be the fame in all bodies,* viz. that inflammation in coals, candles, wood, &c. arifes from letting loofe concreted phlogifton from thefe fubftances into the air.——*Inflammable air* being eight or ten times lighter than common air, rifes from bogs, and putrifying fubftances into the higher regions of the atmofphere, and lodging there, frequently receives inflammation from lightning or electricity, giving *thunder* its long progreffive found——*Lightning* the property of fpreading over the whole hemifphere——and when by winds it is drawn into long ftreaks acrofs the hemifphere, and receives from electricity inflammation at one end, the inflammation runs acrofs the hemifphere, and we call the phænomenon *falling ftars, fiery dragons, meteors, Will-o'th'wifps,* &c.——A foap bubble, filled with inflammable air, rifes in the atmofphere like a cork in water, and is an air-balloon in miniature, rifing from its fpecific levity, and was made by the Author twelve years before any balloon appeared in France. *Inflammable air,* when mixt with an equal quantity of common air, or a third of dephlogifticated air, explodes when confined in a gun, and inflamed by electricity, fo as to difcharge a ball with a force nearly equal to gunpowder.

Copper and ſpirit of ſalt produce an air (thro' quick-ſilver) that is very noxious,—quickly abſorbed by water,—and a candle burns green in it. Water ſaturated with it is a ſtrong ſpirit of ſalt, and diſſolves iron with great rapidity.

Alkaline air is expelled by a candle from a gun-barrel filled with one-fourth pounded ſal-ammoniac, and three-fourths quick lime mixed.

Common air imbibes *phlogiſton*, which diminiſhes *that* air by precipating the fixed air it naturally contains; and it becomes noxious in proportion to the diminution it is capable of ſuffering.—Hence phlogiſton is the beſt teſt of air—unwholeſome as it is more in it, and incapable of diminution; and wholeſome as it has leſs phlogiſton in it. For air imbibing this inflammable matter from the blood in its paſſage through the lungs, performs the office beſt when it has the leaſt phlogiſton in it. Hence candles go out in cloſe rooms, and animals die in them; becauſe air already ſaturated with phlogiſton can contain no more.

Vitriolic acid air is produced by oil of vitriol juſt covered with olive oil in a vial, and diſcharged by a candle through quickſilver. Ice inſtantly melts in this air; and alkaline air put to it produces a white flaky precipitation.

Fluor acid air is forced by a candle from a vial containing pounded ſpar and oil of vitriol, through quickſilver into water. The phlogiſton in the ſpar gives volatility to the vitriolic acid, ſo that, coming into contact with the water, they unite, and the ſtony matter of the ſpar precipitates in flakes, cruſts, &c. a true ſilicious earth.

Dephlogiſticated air, (called alſo *Vital air*; *Empyreal air*; and the *Oxyginous principle)* ſeems to be derived from earth and the nitrous acid, and bids fair to rob us of a received element. It is expelled from nitre

in a glaſs retort by a ſmart fire; alſo from red lead and ſpirit of nitre, out of a gun-barrel or a thin vial —or any earthy matter void of phlogiſton, as pipe-clay, &c. In a given quantity of this remarkable air an animal will live near ſix times as long as in the ſame quantity of common air! A candle burns with an aſtoniſhing brightneſs in it, — a firebrand crackles in it - red hot iron melts in it—— and inflammable air explodes prodigiouſly loud in it, &c. for dephlogiſticated air is one of the ingredients of inflammability.

All ſubſtances, vegetable, animal, or mineral, mixt with nitrous acid, and expoſed to a proper heat, give dephlogiſticated air——if the ſubſtances be firſt deprived of phlogiſton. But if the ſubſtances contain much phlogiſton, (in thoſe circumſtances) they give *nitrous air*. If but a ſmall quantity of phlogiſton, *fixt air*; but if no phlogiſton, the produce is *dephlogiſticated* air.—So when a ſmall quantity of phlogiſton exiſts in the ſubſtance uſed, the *fixt* and *dephlogiſticated airs* generally come over together.

From the ſmoke——putrid effluvia——calcination of metals——and breathing of animals, the air muſt be continually contaminated, and made unfit for human reſpiration. Providence has wiſely made the vegetable kingdom the cure for this evil, for plants imbibe nouriſhment from putrid and phlogiſtic air at their leaves as may be ſeen by the ſuperior vigour in plants growing near great cities - by their growing on walls without earth—and by a green plant put in noxious air, which imbibes nouriſhment, and cures the air at the ſame time. The air ſo purified in leaves and plants, leaves them, and becomes dephlogiſticated, if the leaves and plants be expoſed in water in a tall inverted glaſs, and expoſed to the light.

Reſpiration is alſo a phlogiſtic proceſs, affecting air in the very ſame manner as putrefaction, effervefcence of iron filings and ſulphur——calcination of metals, &c.

—diminiſhing its quantity and ſpecific gravity, and rendering it unfit for reſpiration and inflammation——yet ſtill capable of being reſtored by agitation in water, or a contact with vegetables. Air comes nearly in contact with the blood in its paſſage through the lungs, giving phlogiſton to it when it wants, and taking phlogiſton from it when it has too much. Too much phlogiſton renders the blood black and thick—but the air having accefs to it, even thro' the veſicles of the lungs, renders it red again—and *dephlogiſticated air ſtill more perfectly* ſo, both in and out of the body—congealed as well as fluid, &c.

That *water* is preſent in *air*, is evident from ſeeing it precipitate in a cloud as a receiver is exhauſting on the air-pump; from the *dew* on windows, or other cold bodies when water ſtands for ſome time in a hot room; from the wet hair of thoſe who aſcend the ſides of mountains; and from its entering ſpunges and hygrometrical inſtruments when hung in air; from many more proofs 'tis evident that *air is a menſtruum for water*. *Air*, lying on *water*, and rubbing perpetually againſt it, from this contact, and their natural attraction, the two fluids, mutually imbibe one another; (for air may be ſeen in water placed in an exhauſted receiver.) That an *heavy* body can riſe in a lighter one when its particles are ſeparated, and its ſurface by that means encreaſed, is certain from *gold* being diſſolved, and of courſe hanging in *aqua regia*, —*copper* in *aqua fortis*, &c. *Water* riſes in *air* by the ſame law; and the ferment occaſioned by all ſolutions may be ſeen in the air along the ſurface of wet ground, on a warm day, in that *quivering* which the rays of the ſun ſuffer in paſſing through air and water not yet *intimately mixed*. *Heat aſſiſts all ſolutions*,—hence the quantity of clouds and rain where the ſun is vertical:—The drying quality of the air in ſpring, and the rains and fogs in winter; for ſummer's warmth aſſiſts in filling the air with water, and the winter's cold condenſes and brings it down in high latitudes; and as the higher regions of the air are cold, and thin, little aſſemblages of particles are diſ-

erfed through the air and form *clouds*, about the height of the mountains :——The winds, and their own attraction, affift this junction—till they become big enough to precipitate in a *drop of rain:* If the drop is frozen in its defcent, it falls on the ground an *hail-ftone:* If the *cloud* be frozen, then broken fragments of it defcend in *flakes of fnow. Fogs in an evening* are occafioned by the cold condenfing the vapours new raifed from the ground before they are thus chemically united with the air.

LECTURE VI.

HYDROSTATICS.

THIS branch of philofophy treats of the *nature*, *gravity*, *preffure*, *and motion of fluids* in general, and of weighing folids in them. *Water*, like *air*, confifts of *round* and *hard* particles, as is proved by putting falt in water without increafing its *bulk*, by the *round* pores of aquatic plants and the *Florentine experiment*, which forces water thro' the pores of a copper ball: Hence 'tis evident *there are vacuities in fluids*, and that no fluid can be preffed into a *lefs fpace* than it naturally poffeffes, except *air* and *fteam.*

Fluids are faid to be *perfect* or *imperfect*, as their parts flide with more or lefs eafe over one another, therefore quickfilver is the moft perfect of all fluids. Water being of the *imperfect* kind is feldom *pure:* It adheres to any fubftance it meets with, mixes with its particles, and thence becomes inpregnated with whatever *ftrata* it runs over: If water has any thing alkaline in it, the *fyrup of violets* turns it *green*; if any thing acid, the *fyrup* turns it *red*; if it has run over *iron ftone*, or *iron ore*, a folution of *galls* turns it *black*, and if allum, *oil of tartar* turns it *thick*, &c.——Hence water impregnated with lime-ftone, and oufing flow amongft moffes, leaves, &c.——as the water evaporates, the ftoney matter adheres to thefe fubftances, and affuming their fhapes, gives that variety of whimfical petrefactions we meet with in Derbyfhire,——the dropping well at Knarefborough, &c.

Water being *incompreffible* will not be more *denfe* at the *bottom* than the *top* of the fea; but will have the wonderful property of preffing, *upwards* and *fideways*, as forcibly as *downwards*, in proportion to its *perpendicular height*, with-

out any regard to its *quantity*; for as each particle is quite free to move towards that part on which the preſſure is *leaſt*; and hence no particle or quantity of a fluid can be at reſt till it is *every way equally preſſed.* A fluid may therefore be conceived as made up of *perpendicular columns of particles*, and as divided into *imaginary ſurfaces* each an inch or more from one another, the loweſt preſſed with the weight of *all* the reſt, &c. hence the pipe fixed under the *moſt* ſurfaces will diſcharge the *moſt* water, &c.

To prove that fluids preſs in all manner of directions alike, take four *glaſs tubes*, open at both ends, but bent into all kinds of angles; if theſe be put in water nearly to their tops, the water will riſe in them to its own level. Or take a veſſel full of water, with a hole at the *bottom of its ſide*, of the ſame ſize as one in its *bottom*, and the two holes will be found to diſcharge the ſame quantity of the fluid in the ſame time.

That fluids preſs in proportion to their depth, without any regard to their quantity, is evident, 1. From a *bladder* tied flaccid over one end of an open *cylinder of glaſs*; if water be poured into it, the bladder will bulge *downwards*; but then if it be immerſed in a veſſel of water till the ſurface of the water within the cylinder be *even* with that in the veſſel, the bladder will then be *flattiſh* as if it were not preſſed at all, for indeed it is then preſſed equally. If the cylinder be plunged *deeper*, the bladder will be preſſed *upwards*, ſhewing that bodies ſwim merely by the force of the pillars of water under them endeavouring to riſe to their level. 2. *Lead* is about $11\frac{1}{3}$ times heavier than its bulk of water; if therefore a piece be held tight to the mouth of a cylinder, (open at both ends) by a ſtring within the cylinder, and let down into water above 11 times its thickneſs, the ſtring may be let go, and the upward preſſure of the water will hold the lead to the cylinder; but if the cylinder and the lead be raiſed till the lead is not $11\frac{1}{3}$ times its thickneſs below the ſurface of the water, it will then fall of and ſink. 3. If a cube of 34 inches, open at one end, and filled with quick-

ſilver, have its open end immerſed in a baſon of quickſilver, hung ſo by ſtrings that it may be *let down* into a deep veſſel of water, according to the depth the veſſel is *ſunk*, the mercury will *riſe a fourteenth part* in the tube, and demonſtrate that quickſilver is fourteen times heavier than water. 4. If lead with a *flat upper ſide* be laid on the bottom of a veſſel, and a piece of *flat* wood be held on while the veſſel is filling with water; if no water can get in between the lead and the wood to form an *upward preſſure*, the wood will be held on the lead by its own weight and that of the water above it. 5. If an *empty bottle*, juſt made ſo heavy as to ſink in water, be corked, and ſuſpended at one end of a balance, and, with its cork pulled out, be immerſed in water and filled, it will require as *much weight* in the oppoſite ſcale to pull it up, as will weigh all the water in it, which ſhews that fluids weigh juſt as much in their *own* element as out of it. 6. If a ſmall tube 30 inches long, open at both ends, and to one end (bent to a right angle) it has a *large bladder* tied; if then the bladder be put in a box, and a board be laid on it with 25 or 30lb. weight upon it, and water be poured into the tube, the bladder will raiſe the weights, though the bore of the tube ſhould be ſo ſmall as not to hold an ounce of water. 7. *The preſſure of a fluid upon the bottoms of all veſſels whatever, is proportional to their baſes and perpendicular height, without any regard to the quantities they contain*; for if on a looſe piſton ſuſpended on a balance, a column of water of a foot be weighed, it will be found to weigh as much as a column of water of the ſame height, though contained in a flanging veſſel that holds ten times as much. 8. If a *ſmall tube* be joined to a *very large one*, and the whole be bent in the bottom ſo as the two parts may be either *parallel*, or make *any angle*, water may be poured into *either tube*, and it will juſt riſe as high in the *other*, even tho' one ſhould contain ten thouſand times as much as the other does: This alſo ſhews that fluids preſs in proportion to their perpendicular heights, without any regard to their quantities; that water in pipes will aſcend to the *level* of *the ſpring* from whence it came; and that *jets* or *fountains*

would rife the *fame height*, if not obftructed by *angular turnings*, and the *refiftance of the air* into which they play.

Smoke does not rife into air becaufe of its *pofitive levity*, but becaufe it is *lighter* than the air where it is produced; hence if the fmall neck of a bolthead, full of water, be immerfed in a glafs of wine, the *lighter wine* will afcend up into the bolthead, and the *heavier water* defcend into the glafs. For the fame reafon, a body fpecifically (or bulk for bulk) *heavier* than water will fink in it; a body of the *fame weight* will lie indifferently any where in it; and one fpecifically *lighter* will of courfe fwim in it.

Smoke is forced up a chimney by the air in the room, preffing to the rarefied air *in* the chimney;——hence, the patent ftoves, contracting the fire-place, obliges the air to rufh *in* with great violence, and thereby it overcomes more effectually any wind that forces the fmoke *down* the chimney.——Kitchen, or other open chimnies, are very liable to fmoke with winds coming *over*, or bofoming *againft* a taller houfe, church, tree, &c.——becaufe the fmoke rifing very flow and languidly by its fpecific lightnefs in the open air, or wide chimnies, is eafily puffed down by the wind, if a ventilator or a feathered covering do not prevent it.

If a ftick be counterpoifed on a fcale-beam by water, and after that immerfed in a veffel full of water, it will caufe fo much of the water to flow over the brim as will be fupplied by *that* in the oppofite fcale: Hence it is evident a *fhip* difplaces juft fo much water in the fea as is equal to its own weight and cargo: And hence alfo the *ftrength of wood* may be judged of; for if a piece of oak of a foot long be immerfed in a narrow veffel of water, it will be found to fink about eight-tenths of its length: Beech about feven-tenths; Mahogany feven-tenths, &c.

A folid body, heavier than its bulk in water, will lofe juft fo much of its weight when fufpended in it, as its bulk of water weighs: But the weight loft by the folid is commu-

nicated to the fluid. Hence if the weight of a body in air be divided by what it loſes in a fluid, the quotient will ſhew how much heavier it is than its bulk of that fluid, or its *ſpecific gravity.* By this trial, *pure gold* is found to be 19,637 times as heavy as its bulk of water: *Guinea gold* 17,793 times as heavy: *Quickſilver* 14 times: *Lead* 11,325 times: *Standard ſilver* 10,535: *Copper* 9: *Plate braſs* 8: *Steel* 7,85: *Iron* 7,645: and *block-tin* 7,32. A cubic inch of braſs loſes 233⅓ grains of its aërial weight in water: In proof ſpirits it loſes 235 grains? therefore a cubic inch of water weighs 233⅓; and a cubic inch proof ſpirits 235 grains: And the ſpecific gravities of *pure ſpirits*, *proof ſpirits*, and *water* are as 840,923 and 1000. From hence may be conceived the great uſe of the hydroſtatic balance.

A *pipe* fixed *four times* as deep below the ſurface of a fluid as another of the ſame diameter, will diſcharge *twice* as much in the ſame time; if *nine times* as deep, it will diſcharge *three times* as much, &c. agreeable to the ſquare root of the depth: And the *velocity* with which a fluid ſpouts at any depth below the ſurface, is equal to that which a body let fall *that height* would acquire. Pipes alſo diſcharge a fluid (when placed at equal depths below the ſurface) agreeable to the ſquares of their diameters, *i. e.* a pipe *twice* the diameter of another will diſcharge *four times* as much of the fluid, in the ſame time; *thrice* the diameter, *nine times* as much; four times the diameter, *ſixteen times* as much, &c.

The preſſure of water againſt banks, the ſides of containing veſſels, &c. is in the proportion of falling bodies, viz. if the preſſure againſt the firſt inch deep of the veſſel be one pound, it will be three pounds preſſure upon the inch below that; five pounds againſt the inch below that; ſeven pounds againſt the inch below, &c. ſo that preſſure againſt banks, flood-gates, &c. is as the ſquare of the depth, *i. e.* if the preſſure be one pound againſt the uppermoſt inch, it will be four pounds againſt two inches deep; nine pounds againſt three inches deep;

fixteen pounds againſt four inches deep; twenty-five pounds againſt five inches deep, &c.

Fluids *preſs*, or *reſiſt*, according to their *denſity*; and hence a boat will carry more on *ſalt* than *freſh* water. *The hydrometer* ſhews *this* very perfectly; it is buoyed up by *ſalt and water* mixed with *vinegar*, &c. but ſinks in *wine*, *ſpirits*, &c. according to their lightneſs, and hence it is uſed for trying the lightneſs or ſtrength of liquors.

A *ſyphon* acts agreeable to that *equal ſtate* which nature affects through all her operations; it will not run unleſs the height of water in the *outer* leg be greater than that of the *inner* leg above the water in which it is immerſed; as the water falls therefore from the *outer* leg, it will make a continued *vacuum*, and of courſe the *preſſure of the atmoſphere* on the ſurface of the water will force it through the ſyphon in a *continued ſtream*, if kept free from that lodgment of air which frequently takes place on the top of the ſyphon. By the *Tantalus cup*, and *fountain at command*, the cauſe of *intermitting ſprings* is explained thus:

Clouds, being attracted by the mountains, give a continued ſupply to thoſe reſervoirs of water which are frequently found in the bowels of mountains, and which ſupply *ſprings* in general: But ſhould the channel from one of theſe reſervoirs be formed like a *ſyphon*, of courſe the ſpring which proceeds from it will *ebb* and *flow* like the ſea, as thoſe in Derbyſhire, Berkſhire, &c.

The action of the *common pump* depends on the *preſſure of the atmoſphere*: When the piſton is drawn up, the column of air upon it is alſo lifted, and a vacuum is formed underneath it, the preſſure of the atmoſphere on the well will then force the water up the pump 33 feet, but not higher; which ſhews that a column of water of *that* height is equal to the weight of a column of air, of the ſame thickneſs, reaching from the earth's ſurface to the top

of the atmofphere. Therefore at any diftance above the furface of the well lefs than 33 feet the pifton will work, and water from thence may be lifted to any height whatever, if the pump be ftrong enough. In a *forcing pump*, the pifton is *a folid plunger*; it raifes the water above the fucking-valve as in the laft, but when the plunger defcends (as the water cannot return through the valve back again) it forces it into a larger air veffel which communicates with the body of the pump above the fucking-valve; and as by this force the air in the veffel becomes condenfed, its re-action on the water caufes it to flow through a fmall pipe in a continued ftream. The engine for extinguifhing fires confifts of two fuch forcing pumps, with their air veffels.

The *lifting pump* can only be ufed in deep water, as its pifton is worked by a rod going in at its bottom, and faftened to a frame coming up each fide of the pump: This pifton has a valve opening upward, and it works below the furface of the water in which the pump is immerfed, and thence has no occafion for the air's preffure, or a fucking-valve. This pump is generally equipt with an air veffel as the laft. On this principle engines are made for raifing water above the level of rivers or fprings, as at Marli; but if three pumps are worked in any engine by a triple crank, and all of them throw their water into one pipe, there is no occafion for an air veffel, becaufe there will be always one or other of the piftons acting, fo as to force the water out in a regular ftream.

Archimedes' fcrew pump raifes water by its endeavour to fall—'tis three or four hollow threads of a fcrew wound round a folid cylinder; it muft rife out of the water floping, fo as the threads may all incline downwards; then, when 'tis turned round, water will rife in it, but to no great height.

The *upright cylindrical mill*, by Dr. Baker, is a tall tube of wood or metal, twenty feet high, and about five inches diameter; it ftands on a point perpendicular, and has as to

its bottom two or more horizontal arms, or tubes, fixed, of about ſix feet long, communicating with the upright, tube, and perforated with holes, one in each arm and on the ſame ſide in each; through theſe holes the water which flows in at top ſpouts out, and by giving a puſh to the air, and preventing the water's preſſure on that ſide the arm, forces the whole machine round, and carries a pair of ſtones at top, or pumps, or any thing elſe capable of being moved by a circular motion.

The *bucket engine*, for raſing water by pumps out of mines, &c. is well calculated for ſituations where the ſtream that carries it has three yards of fall, and is too ſmall to carry a wheel: The bucket hangs on one end of a beam like that of a fire engine; and at half the diſtance from thence to the fulcrum hangs the pump rods; on the other end of the beam hangs a counterpoiſe, rather heavier than the empty bucket, and a column of water on the piſton; but when the bucket is filled by the ſtream, *it* is heavier and deſcends; the bucket hangs on centres a little on one ſide its centre of gravity, ſo that one ſide is heavier when empty, and the other when full, and being unlocked by its deſcent, its unequal poiſe turns and empties it, and then it aſcends and opens a valve which again lets the ſtream into it, and makes it deſcend again. This motion works the pumps.

Two forcing pumps, for ſupplying houſes with water, are alſo worked by an engine of ſimilar principles, but with ſtill greater ſimplicity: A beam inclining downwards to each end from the center on which it hangs, has a trough cut in it, from a diviſion in the middle down to each end, where buckets are fixed for receiving the water that works it, and which flows into the trough, firſt on one ſide the diviſion and then on the other, as the ends riſe and fall: When one bucket deſcends, the valve in its bottom falls on the pin, which opens it, and lets out the water; mean while the ſtream is filling the other bucket, which, when full, deſcends in like manner, and each end works a forcing pump.

The *centrifugal machine* claims ſtill greater merit as to its ſimplicity; its ſhape is like the letter T, 'tis hollow throughout, and its three ends are open: When the loweſt end is immerſed in water, and it is whirled round on that end, the air in the arms will be partly thrown out by the centrifugal force, and conſequently the preſſure of the atmoſphere on the ſurface of the water into which it is immerſed will force it up the tube and throw it out at the arms; hence a continued vacuum is made, and of courſe a continued ſtream thrown out. The perpendicular tube muſt not be above 33 feet high, for reaſons already given. Two men will diſcharge near three times as much water with this machine, in the ſame time, as with any pump yet invented.

Several Models to ſhew how a Ship may pump herſelf.

The *fire* (or rather *ſteam*) *engine* is one of the nobleſt preſents that art has made to the neceſſities of mankind! When the particles of *water* are ſeparated by fire, they compoſe an *elaſtic vapour*, called *ſteam*; this vapour is capable of occupying 14,000 times the *ſpace* it did in its ſtate of *cold water*; 'tis of force ſufficient to drive away the air, and it may be condenſed, or brought back to water again by *cold.* Hence a long hollow *cylinder* of iron communicates with a huge and cloſe *boiler*, half filled with water, by a neck which can be opened or ſhut by a ſliding valve called a *regulator*: The *cylinder* is exactly filled by a *piſton* made *air-tight*, that hangs on one end of a *beam* of timber about 20 feet long, and ſuſpended on a centre like a ſcale-beam; at the other end of the beam hang the *rods* which work the *pumps* in the bottom of the *mine*, and throw up a part of the water into a *reſervoir* on the top of the building: From this *reſervoir* there comes a *pipe* under and through the bottom of the *cylinder*, that by opening the cock (called the *injection cock*) plays a *jet* of cold water into the *cylinder* to condenſe the ſteam; after which this water falls through a pipe (with a valve opening outward) and forms the *hot-well:* Another pipe alſo, with a valve outward, called the *ſnifted valve*, is fixed near the bottom of the cylinder,

and ſerves to let out the *air* or *ſteam* without letting it return. The *regulator* or *injection cock* are alternately opened and ſhut by a piece of timber hanging from the large beam; and a ſtream is let into the *boiler*, or ſtopped, by a floating *copper ball* in the boiler that regulates the height of the water. If now a *large fire* be put under the boiler, and the ſteam let into the cylinder by opening the regulator, it will drive out the air, and poſſeſs the ſpace itſelf; but ſo ſoon as the *injection cock* is opened, a *jet* of *cold water* will play into the ſteam in the cylinder, and *condenſe* it into a *few drops*; hence a *vacuum* is formed in the cylinder, and the *preſſure of the atmoſphere* on the *piſton* will force it down to the bottom of it; the ſteam then being let in again will counteract the air's preſſure, and with the weight of the pump rods on the oppoſite end of the beam, bring up the piſton to the *top* of the cylinder. This action is repeated *fourteen* or *ſixteen* times in a minute, and works the pump in the mine. As the *friction* of this machine is very great, inſtead of reckoning 15lb. preſſure on every ſquare inch on the piſton, 8lb. will be found nearer. If then the weight of a column of water, the depth of the mine, and the diameter of the pump be calculated, the neceſſary diameter of the cylinder will be eaſily found.

The *fire engine with the inverted piſton* ſpares the expence of both a *beam and building*; the cylinder, with its open end downwards, ſtands over the pit or ſhaft of the mine, the boiler ſtands by its ſide, the *injection well* above it, and to its *piſton* the *pump rods* are faſtened. The *regulator* (of great ſimplicity) is the *injection cock* alſo. When the ſteam is let in at the top of the cylinder, and condenſed by the injection water, the *upward* preſſure of the atmoſphere forces the piſton from the bottom to the top of the cylinder, and the weight of the rods, and ſtrength of the ſteam force it back again. This motion works the pumps.

The *cold water vacuum* will do this buſineſs with ſtill leſs *machinery* and *expence*, where the water that works it has a fall of 40 feet. With the bottom of the cylinder there communicates a perpendicular wide pipe of 33 feet

long, having a regulator at its bottom, and another at its top. The piston and beam are the ſame as in the common *fire engine.* The water being let in at the bottom of the cylinder will fill both the cylinder and the pipe below it; if then the regulator at the bottom be opened, the water will deſcend out of the *cylinder*, but not out of the *pipe*, becauſe it is *then* but a *counterpoiſe for the atmoſphere:* Thus a *vacuum* is formed in the cylinder, and the piſton will *deſcend* and ſhut the upper regulator; but when it reaches the bottom, it opens again, and as the cylinder fills, the piſton riſes. Thus action is given to the beam, and *water* applied in this way is perhaps a more *powerful agent* than it is in any other.—N. B. *For ought I know, theſe two engines are new, and unknown to the public.*

Watts' and Boulton's ſteam engine condenſes the ſteam, without cooling the cylinder by a jet of cold water, and thereby ſaves fuel. The ſteam is produced in a boiler as uſual—it paſſes into a double cylinder, and forces down the piſton by its elaſticity, for the rod of the cylinder works through a collar of leathers, and therefore the preſſure of the atmoſphere has nothing to do in this engine. When the piſton is at the bottom of the cylinder, the ſteam-cock opens, and by the double cylinder, ſteam enters both above and below the piſton, ſo that it riſes in ſtagnate ſteam by the weight of the pump rods acting on the oppoſite end of the large beam. When the piſton arrives at the top of the cylinder, a cock opens that communicates with a vacuum formed in a pond of cold water; this draws the ſteam from *under* the piſton in a moſt perfect manner; and leaves the piſton liable to the preſſure of the ſteam *upon its top:* and as ſteam may be made of much ſtronger preſſure than the atmoſphere, this engine is proportionably more powerful than the common engine.

Theſe, and many other hydraulic machines for various purpoſes, are too cumbrous to be removed from the ſtationary lecture-room.

LECTURE VII.

ELECTRICITY.

ELECTRICITY and *phlogifton*, having many properties alike, many think them only modifications of the fame principle. Iron lofing its phlogifton by vitriolic acid, lofes by the fame procefs its electricity; proved by infulating the procefs, when a wire communicating with the effervefcing mixture, will betray figns of negative electricity. This moft fubtil fluid, feems more or lefs inherent in all matter—but fome bodies conduct or tranfmit it, whilft others ftop its progrels from one body to another. Glafs, hair, filk and gums are *non-conductors*, and called *electrics*: but metals, water, green wood, and moft animal and vegetable fubftances are *conductors*, and are called *non-electrics*. 1. If a long tube of glafs be rubbed with warm filk, an atmofphere of this fire will be formed all round it, and if a finger approachesthe tube, the fire will come vifibly off the tube into the finger with a fnap: The reafon is, the friction collects the fire, from the earth (its grand refervoir) and the fpark is the effort it makes to difperfe itfelf again, and thereby reftore its equilibrium. 2. If the fame tube electrified, approaches, a *feather* hung by a filk thread it will *attract* the feather once, but if held to it again will repel it. The filk will not conduct the electric fire; the equilibrum is therefore effected between the tube and the feather on the firft approach; on the fecond, the atmofphere of the tube preffing on that of the feather drives the feather from it, (for two bodies poffeffed of the fame electricity univerfally repel one another;) but if the feather be fufpended by a flaxen thread, the electrified

tube will always attract it, becaufe the fire can make its efcape up the thread, and thereby leave a continued inequality between them. A *large globe* or *cylinder* of glafs, with a *bafil-fkin cufhion* covered with an amalgama of quickfilver and tinfoil, or zink, or aurum mofaïcum fpread on black filk, faturated with mercurial ointment, to produce the friction; a *prime conductor* to take off the *electric atmofphere* from the glafs, and depofit it in a *glafs receiver* covered in and outfide with tinfoil to within two inches of the top, and a *wheel* to put the cylinder in motion, is called the *electric machine*, or *fire pump*. An electric machine of great power is alfo made of oil'd or gum'd filk drawn between rubbers of cat's-fkin with the fur on. When a machine is put in motion, it difturbs the equilibrium of the *electric* fire about it, and from thence the whole of its phænomena proceed, as may be proved by experiment. 1. If a perfon touch the electrified conductor, the fire will efcape from it through the perfon into the ground with a flafh and report. 2. If any number of perfons take hands, and the firft perfon holds a chain which communicates with the *outfide* of the receiver, and the laft perfon touches the communication with the *infide* when the phial is charged, the fire will reftore itfelf through all the company at the fame inftant, giving each a fevere fhock at the wrifts and elbows, in its paffage back again to the *outfide* of the phial. 3. If a perfon ftands on a ftool with *glafs feet*, and holds a chain faftened to a conductor, on turning the machine, and touching him, fparks may be brought out of every part of his perfon and cloaths, and if he touch warm fpirits or gunpowder with his finger, they will take fire; which fhews that the electric fire is chiefly pumped from the earth, and cannot return to it again through glafs. 4. If a ball be hung on the conductor, and a plate of *bran* or *leaf gold* be placed under it, on electrifying the ball, the bran will be alternately attracted to and repelled from it in a beautiful fhower; here, the particles of the bran are carriers as it were of the electric fire from the ball to the plate: And if two

bells be hung on the conductor, one by a flaxen thread, and the other by a filk thread, (having from it a chain to the table) if a fmall *clapper* be hung between them on a filk thread, it will carry the fire from one to another and thereby ring both. 5. *Electrified feathers* fpread out their threads radiently ; if a round body be held to them they *cling* to it and depofit their fire ; but if a point be held near them they fhrink at once; hence the reafon why the wire conductors rifing from the ground above the tops of houfes, terminate in points to receive with more eafe the *lightning* from the clouds, and thereby prevent its mifchief. 6. If *wires* fixed like the fpokes of a wheel be fufpended on their center, with their points bent all the fame way, and in the plane of the circle ; on being electrified, the effluvia flowing from the points will ftrike fo forcibly upon the air as to force the wheel round with great rapidity : Hence a fimply and pleafing electric orrery is put in motion, and various mills and other devices. 7. *Water* and *falt* (like the cylinder and cufhion) will collect the electric fire when put in motion ; for one is an *electric*, and the other a *non-electric* body ; hence the *fea* itfelf becomes as it were an *huge electrical machine* when violently agitated by winds, collecting on its troubled furface the fire from beneath, and looking in the night as if it was all in flames. *Clouds* raifed from a fea fo circumftanced, muft needs contain more of the electric fire than clouds raifed from the land, or calm fea; if therefore two clouds meet, fraught with *unequal portions of this fire*, the cloud *more* electrified will depofit its abundance in the cloud *lefs* electrified, and with a flafh of lightning reftore the equilibrium; this fire driving to a diftance the air that furrounds it — the ftroke formed by the return of that air is *thunder*. Some think putrid fifh, others animalcula, or an eaft wind, the caufe of the luminous appearance of the fea. If a cloud attracted by a neighbouring mountain contains *more* electric fire than the mountain, the lightning will dart from the cloud to the mountain and vice versâ ; hence if an electric cloud comes too near a *tower*, *tree*,

horſe, &c. and they are not wet, the fire will deſcend on them in an effort to reſtore the equipoiſe, and if greatly obſtructed in its paſſage to the earth, will perhaps break them all to pieces; to ſtand under a tree or ſhed, is therefore dangerous in a thunder ſtorm; and ſhews alſo the extreme utility of having a wire from the top of any tall building, down which the equlibrium will be reſtored without danger; and if the wire does not touch the ground, a finger at that time applied to the wire, will receive the *electric flaſh* much ſtronger than by a machine. A *kite* ſent up into the thunder-cloud by a wire, having a key tied to its end, and held by a ſilk ribband, will extract the fire from the cloud; it will come down the wire, and ſtream off the key to the ground in a beautiful, but alarming torrent of fire.

'Tis thus, by weight and meaſure, the ALMIGHTY has appointed ſelf-phyſic for the diſorders of his works!

If a *capillary ſyphon* be made to decant water, it will fall from it in *ſmall drops*, but if the water be electrified it flows from the ſyphon in a *ſwiſt ſtream.* Hence 'tis found that a perſon *poſitively electrified*, (*i. e.* having more electric fire thrown into him than his *natural quantity*, by ſtanding on a cake of wax, or a glaſs-footed ſtool, and touching an electrified conductor) has his *pulſe accelerated.* This acceleration has been found of great ſervice in *obſtructions*, *rheumatiſms*, *palſies*, *&c.* and the *electrical ſhock* has been ſtill more ſucceſsful in removing *paralytic complaints*, *deafneſs*, *tooth-ach*, *numbneſs*, *&c.* Sparks drawn from chilblains, ſwellings, &c. have a great effect, and the aura from a wooden point has diſperſed the cataract of the eye.

The electrical fluid always goes the neareſt, and chuſes the beſt conductors. A chain hung on a wall, and made part of the circuit from the *in* to the *outſide* of the charged Leyden vial, is luminous when the vial is diſcharged,

and ſhews the road taken by the electrical fluid: but if a ſtraight wire touch the two ends of the chain the chain will not be luminous, for the fluid will run inviſibly thro' the wire, as being the *nearer* road. If the wire be then removed, and a ſtick put into its place, the chain again becomes luminous in the diſcharge, as the fluid will rather go a longer diſtance than paſs thro' a bad conductor.

The electrical fluid poured on the inſide coating of a Leyden vial, propels an equal quantity from the outſide. 1. The outſide coating of a vial being pieces of tinfoil not touching one another, the fire will be ſeen darting from one piece to another, till the charge is compleated: when diſcharged the fluid will return, and make the whole outſide luminous. 2. A bottle, coated on both ſides, having a cap cemented on its neck, with a valve, and from that cap a pointed wire going ſtraight into the bottle: If this bottle be exhauſted of its air, (but not to a vacuum) it will be found a good conductor; and when the cap is held to the prime conductor, flames like the Aurora borealis will iſſue from the point of the wire to the inſide coating, and charge it;——but while an imperfect communication is made between the negative outſide and the poſitive inſide, the point receives the fluid, and exhibits only a ſtar on its point:—Hence a *receiving* point always exhibits a *ſtar* and a *delivering* point *flames* in an imperfect vacuum. Rarified air being ſo good a conductor, may not the ſun's heat and the great centrifugal motion of the equatorial parts of the earth, make the air there ſo thin, as to become a conductor of that electric matter of which the earth is the known reſervoir? and being thus thrown up into the upper regions of the atmoſphere, may it not make its way towards the poles, where the ſmall degree of centrifugal force is friendly to its reception? Aiming therefore at a point, may it not be ſo far concentrated and condenſed, as to become viſible, and make thoſe radient corruſcations we call *ſtreamers?* for electric matter ſtreaming through highly rarefied air exhibits the very ſame appearance.

3. On the cover of a large Leyden jar, fix a ſmaller jar, ſo that the *outſide* coating of the ſmall jar may have a metallic communication with the *inſide* coating of the larger;——the outſide coating of the ſmall jar becomes a conductor to the inſide of the big one, when held to an excited prime conductor; if when charged, one knob of the diſcharging rod be applied to the negative ſide of the large jar, and the other applied to the knob communicating with the inſide of the ſmall jar, a flaſh will iſſue from the contact (being the natural electricity of the inſide coating of the ſmall jar) and by which the equilibrium of its two ſides becomes deſtroyed. Electricity will then riſe from the inſide of the large jar upon the outſide of the ſmall one. This balance is again reſtored by forming a metallic communication between the *in*, and *outſide* coatings of the ſmall jar. By repeating theſe twenty or thirty times, the whole charge of the lower jar will be taken piecemeal out; and prove that what electricity is poured on one coating of a jar propels a like quantity from the other. 4. If a rod of wire, 18 inches long, having a light knob at each end, and ſuſpended on an inſulated point, be placed ſo between the knob of a charged jar and a metal pillar, that when one knob touches the pillar, the other may be ſix inches from that of the jar, then will the rod vibrate between the jar and the pillar, taking out the electricity ſo by little and little as to acquire ten minutes to compleat the diſcharge. 5. If a Leyden vial be charged on an inſulated ſtool, having two pith balls hanging by fine threads projecting from its in and outſide coatings, the balls communicating with the poſitive coating will ſeparate; if then a finger touch the wire on which they hang, theſe balls will cloſe, and thoſe will open which communicate with the *negative* coating; touch that wire and the negative balls cloſe, and the *poſitive* balls open, &c. for an amazing number of times! ſhewing, that though glaſs will not conduct electricity, the electric influence can operate through the thickneſs

of glafs. 6. To fuperinduce electricity on a loofe coating laid on plate-glafs, touching the coating with the knob of a charged vial, then fhake off the coating, and clap an infulated metal plate on the place, touching it at the time of contact, then lift up the plate, and it will give a fpark to the knuckle; place it on the glafs again, and touch and remove it as before, and it will give another fpark, and continue to do fo as long as the apparatus is kept clean and dry; making perpetual electricity, by which vials may be charged, inflammable air guns fired, &c.——N. B. The plate of glafs muft have a fixed coating on the oppofite fide to the loofe one, and of the fame fize. This apparatus is called *Electrophorus*; and often inftead of glafs, a plate is made of fulphur, fhell-lac, rofin, &c. To prove that the natural electricity of bodies may be difturbed by the near approach of excited electrics, let two projecting arms of infulated wood have flips of tinfoil glued on them from end to end, and pith balls hanging from one end of each; if the two arms be placed in a line, with the ball end of one touching the end without balls of the other, and an excited electric be held within an inch of the end without balls, then will all the four balls part;——at that inftant, if one ftand be feparated from the other, the balls of one will be found in a negative and the other in a pofitive ftate, the balls fartheft diftant from the excited electric will be in the fame ftate as the electric, and of courfe repelled by it; the neareft attracted, &c. Hence if any part of an electrical cloud comes near the earth, it will difturb the electricity in the earth, and drive it away; but if any other part of the cloud comes within the ftriking diftance of any conductor to the earth,—the cloud will be difcharged, and the difturbed electricity will return with a force that frequently proves fatal to animals in its way.

Electricity is applied to *inflamed eyes*, *tumours*, *&c.* by a chain coming from the prime conductor ending in a point

of hard wood; the point is held near the part by a glafs handle, and an aura iffues from it on the fore, that often performs a cure. 2. Paralytic and rheumatic patients are relieved by fhocks fent through the fide affected. 3. Obftructions are often cured in the female fex by pofitive electrification, *i. e.* by placing the patient on an infulated ftool, communicating with the prime conductor, and keeping her electrified for half an hour together, occafionally drawing fparks from her.

LECTURE IX.

OPTICS.

Hail holy light! *Offspring of heaven! First born!*
Or of th' eternal coeternal beam;
May I exprefs thee unblam'd?——   MILTON.

THIS *modefty* of the *poet* becomes the dignity of fo divine a fubject.——*Light* is the bleffing which gives poignancy to all others,——therefore the fcience of *optics*, which immediately treats of it, muft reflect part of its luftre and importance. Plato defines light, "*a rare and fubtil flame*;" and perhaps it is but diluted or very rare phlogifton, or flame in a ftate of great thinnefs or rarefaction. May it not be the inflammable principle perpetually let loofe from the fun, and occafionally from other luminous bodies?——May not thefe phlogiftic particles flowing from the fun, enter into the texture of other bodies, give them the power of inflammability, and become fixt in them, till let loofe by the contact of bodies in actual inflammation?——Or finally, that the concreted rays of the fun in bodies having affinity with them, may give them the power of inflammability univerfally, and that colour in bodies may arife from a chemical rejection of the colour reflected to the eye, while all the reft are abforbed into the body? Some believe *light* to exift even in the *abfence* of a luminous body, and that it is only a *luminous body* that puts it in motion. The moft general, and probable opinion is, that it flows immediately *from* the luminous body in ftraight lines, in all manner of directions, and confifts of *particles* fo infinitely

ſmall, as to exceed all human comprehenſion. A proof of this ſmallneſs is, that a *candle* will fill a ſphere of four miles in diameter, without the leaſt ſenſible loſs of its ſubſtance: And if a *row of candles* ſtand parallel to a *black paper*, with a *pin-hole* in it, each candle (through that hole) will make a ſeparate ſpeck on the *paſte-board* a little behind it. Theſe particles by ſtriking the *retina* of our eyes, excites in our minds the idea of light: And when they fall upon bodies, and are by them reflected to our eyes, they excite in us an idea of the colour and ſhape of theſe bodies.

In a room *perfectly dark*, if the hand (or any thing) be put into light, and then taken into the dark room, it will be luminous ſome time, as if covered with phoſphorus.—Calcined oyſter ſhells taken out of the light into the dark room, exhibit the colours of the rainbow, &c. ſhewing that light ſtriking upon bodies, excites their latent light, and makes it viſible, as one candle is lighted from another. Or that light ſticks to bodies plunged in it, as water does to the hand.

We cannot ſee through the bore of a bended pipe; which proves that light moves in ſtraight lines in *every medium* of *uniform denſity*. But when they paſs *obliquely*, out of one medium into another, which is either more *denſe*, or more *rare*, they are *refracted*, or bent towards the denſer medium, more or leſs, as they fall more or leſs obliquely on its ſurface. To prove which, put a *ſhilling* in the bottom of an empty veſſel; ſtand ſo far from it that the veſſel may hide the ſhilling; if water be then poured into it the ſhilling will again be ſeen. Hence we are deceived in the depth of water: A ſtraight ſtick put into water will appear crooked; and hence the *ſun*'s rays being broken by paſſing thro' our atmoſphere, we ſee him in the *horizon*, before he riſes, and after he ſets in it. When *rays* fall perpendicularly on any medium, they paſs ſtraight through without any refraction.

Glaſs is generally ground into eight different ſhapes for optical purpoſes. 1. A *plane glaſs*, is a flat, and even on both ſides, and of an uniform thickneſs; will refract the rays of light, but not collect them into one focus. 2. A *plano-convex*, is flat on one ſide, and a portion of a ſphere on the other. When parallel rays fall directly upon it, they paſs through it, and are ſo refracted, as to unite in a point called its focus, juſt ſo far behind it, as is equal to the diameter of the ſphere of which it is a part. 3. A *double convex*, is convex on both ſides: Parallel rays paſſing through it *converge* or meet in a focus, at half the diſtance they do through the *plano-convex*; and as the heat of all thoſe rays are collected in that focal point, it will burn, melt or calcine all opaque bodies. 4. A *plano-concave* is flat on one ſide and concave on the other. 5. The *double concave* is hollow on both ſides, and parallel rays paſſing through *diverge* or ſpread out agreeable to the laws of refraction. 6. A *meniſcus-glaſs* is convex on one ſide, and concave on the other. 7. A *flated plano-convex*, or multiplying glaſs, has its convex ſide ground into ſeveral flat ſurfaces. And, 8. The *priſm* has three flat ſides, and viewed endwiſe appears like an equilateral triangle. The *priſm* held obliquely to a ray of light in a dark room, will effect its ſmalleſt *particles* the *moſt*, and ſhew them to be a fine *violet colour*; it will aſſemble the next in ſize cloſe to the firſt, and ſhew them to be of an *indigo colour*; the next *blue*; the next *green*; the next yellow; then *orange*; and at laſt the *red*, which conſiſts of the largeſt particles, and therefore by the momentum of their motion, the leaſt capable of being attracted out of their way. 'Tis wonderful that theſe colours occupy ſpaces on the ſcreen on which they are thrown by the priſm, exactly proportionate to the diatonic ſcale of the *ſeven notes of muſic*! If in the rays ſo divided a *double-convex lens* be put, it will bring them into one point that ſhall be perfectly white; which accounts for the *white appearance of light*. As *white* is therefore a compoſition of all colours, ſo *black* is a privation of them all, and properly *no colour*, and ſuch a blank exiſts in the ſpace above our atmoſphere: In looking up therefore we ſee what is called the *blue ſky*, a colour na-

turally reſulting from the mixture of *black* and *white* through which we look; or perhaps blue is the natural colour of the atmoſphere, ſo that diſtant mountains look blue, by being look'd at through a medium of that colour. All bodies appear of that colour whoſe rays they reflect moſt; as a body is red when it reflects the *red rays*, and abſorbs the reſt. Two, or more, colours that are quite tranſparent by themſelves, become dark when put together. Thus, if *ſpirits of wine* be tinged *red*, and put in a ſquare bottle, every object ſeen through it will be *red*; becauſe it only ſuffers the red rays to paſs through it, and ſtops the reſt. If another bottle be tinged blue, all objects viewed through it will be blue for the ſame reaſon: But if the two bottles be held together, the object can no more be ſeen through them; for whatever rays paſs through one bottle to the eye will be ſtopped by the other, &c. Rays of light ſuffer different degrees of refraction, by falling more or leſs obliquely on the *priſm* or *convex lens*, *&c.* and are thereby ſeparated as above; this happens to them in paſſing through *drops of falling rain:* For being *reflected* towards the eye from the ſides of thoſe drops which are fartheſt from the eye, and again *refracted* by paſſing out of theſe drops into the air, they come in refracted directions to the eye, and make all the colours to appear ſucceſſively in the form of a fine arch in the heavens, which is called the *rainbow:* All drops paſſing through an ideal plane in the ſhower, refract a certain colour to the eye——paſſing through another a little lower they refract another, &c. ſo the bow appears permament while the ſhower laſts.

Light is *reflected* by the *repellent* quality of bodies, and flies back from poliſhed ſurfaces, like a ball thrown againſt an hard and ſmooth plane: If a ſtick ſtand perpendicularly on that plane, and the ball be thrown obliquely on the plane near its foot, it will rebound on the other ſide the ſtick, and form an angle with it, equal to that in which it was thrown; the firſt of theſe is called the *angle of incidence*, and the other the *angle of reflection.* If upon a *plane looking-glaſs* a ray falls from any object, if a perpendicular be erected there, and the eye go off ſuch a

diſtance as to form the *ſame angle* on the other ſide of it, the object will be ſeen in a ſtraight line behind the glaſs, —for it is an axiom in optics, *that we always ſee objects in that line of rays that come to the eye laſt.* Hence I ſee my whole perſon in a glaſs but *half* its length; for the rays from my feet ſtriking upon the bottom of the mirror, will form the *angle of reflection* in my eye the ſame as if it was the *whole* length, &c. Hence alſo the effects of *diagonal mirrors, opera glaſſes, cameras,* &c. Parallel rays falling on a *concave mirror* will be reflected alſo agreeable to thoſe *angles,* and meet in a point at half the diſtance of the mirror, from the centre of its concavity; if the rays proceed from an hot ſun, his image will likewiſe be found in that point, and burn. The rays which proceed from any ſmall *terreſtrial object, come diverging* to the mirror, and therefore will not be *converged to a point* at half the diſtance of the mirror's ſurface from the centre of its concavity, but *nearer to that ſurface*; the image will be leſs than the *object*, but will be ſeen *inverted,* and hanging pendant in the air, quite diſtinct by an eye placed oppoſite the mirror. If the *object* be *in* the *centre of the mirror's concavity*, the *image* and *object* will be *together*, and of *equal bulk:* Therefore when the object is more remote than the centre of concavity, the *image* will be *leſs* than the *object*, and between the *object* and *mirror:* But when the object is *nearer* than the centre of concavity, the *image* will be *more remote*, and *bigger* than the object. The angles of *incidence* and *reflection* alſo account for the *ſmall image* in a *convex mirror.*

The *human eye* is lodged in a bed of fat, and ſecured in an hollow orb of bone;—'tis moved by *muſcles* which act on its outſide like *pullies*, and conſiſts of *four coats*, and *three humours*. The coat, in which the *back part* of the eye is contained, is called the *ſclerotica*; it is a *large portion of a globe*, very ſtrong, and of a non-elaſtic nature; —that part which *completes the globe* on the *fore-part* of the eye, is the *cornea*; it bulges a little forward out of that ſhape, and is a fine tranſparent membrane. Next within the ſclerotica is that called the *choroides*, which

ſerves as it were for a *ſoft lining* for the other; and within this, is ſpread a fine expanſion of the optic nerve, like a net, called the *retina*, upon which are painted, as in a *camera obſcura, the images of all well enlightened objects.* The *iris* is compoſed of two ſets of muſcular fibres, which dilate, or contract the *hole* in it, called the *pupil*, ſo as to adapt it to a ſtrong or weak light. The *adnata*, or *conjunctiva*, is the white of the eye, a fine membrane that *folds under the eye-lid*, and joins to it. Under the *cornea* is a fine tranſparent fluid like water, and thence called the *aqueous humour:* It gives the protuberent figure to the cornea, and goes through the pupil. Behind this lies the *cryſtalline humour*, ſhaped like a double-convex glaſs, tranſparent as cryſtal, of the conſiſtence of hard jelly, and which converges the rays that paſs through it to a focus on the *retina.* It is incloſed in a fine tranſparent membrane, from which proceed radiant fibres called the *ligamentum ciliare*, all round its edge, and joined to the outward edge of the *iris:* Theſe fibres, by a power of contracting and dilating, alter the convexity of the *cryſtaline humour*, and ſhift it a little *backward* or *forward* in the eye, to ſuit it to the different diſtances of objects *(an admirable proviſion.)* The *cryſtalline humour* is bedded on the *vitreous humour*, which fills the whole of the other part of the orb of the eye, and is tranſparent like glaſs; this is the largeſt of all in quantity, and is much of a conſiſtence with the white of an egg. The *optic nerve* comes from the *brain*, through the *ſclerotica* and *choroides*, on that ſide the eye next the noſe; and is incloſed on the outſide the eye by coats proceeding from the *pia* and *dura mater*, and of which the *ſclerotica* and *choroides* are but a continuation. Theſe are the parts of this wonderful organ.

Rays from any enlightened *object* ſtream upon the *retina*, and there paint it invertedly, as may be ſeen by cutting off the three coats from the back part of a freſh bullock's eye, and putting a piece of white paper over that part: If the eye is then held before any bright

object, an inverted picture of it will be painted on the paper. The *optic nerve* inclofes a *blood-veffel*, which renders objects invifible that fall on it; how wifely therefore is it placed on one fide of each eye! that the fame parts of an image which fall on the optic nerve of *one* eye fhould not fall on the *other!* If three patches are placed at a foot diftance from each other on a wall, if the *right* eye be covered, and the *left* look ftedfaftly at the right-hand patch, the middle patch will difappear, becaufe it falls on the artery in the optic nerve.

The nearer any object is to the eye, the larger is the angle under which it is feen; therefore an object looks twice larger at *one* than at *two* miles diftance. Hence the ufe of *convex glaffes*, which, by increafing *this* angle, make *minute objects* vifible; and when the *humours* are grown fo flat in decayed eyes, that the picture falls behind the retina, can bring the rays to converge fo that the picture fhall be brought back as it were to the *retina*, Hence alfo the reafon that the *too round* eye requires the *double concave* glafs, by its divergency, to remove the image from the vitreous humour forward to the retina.

The *fingle microfcope* is only a fmall convex glafs having the object placed in its focus; and the eye at the fame diftance on the other fide. Its magnifying power is thus calculated: A good eye cannot fee any object diftinctly at lefs than fix inches diftance; if this be divided by the focal diftance of the glafs, the quotient will be how much the diameter of the object is multiplied.

The *double microfcope* confifts of an *object glafs* and an *eye glafs*, between which the image is formed and magnified, by having the object a little further from the object glafs than its principle focus; this image, brought fo near, is viewed by the eye through the eye glafs. If each glafs magnifies *fix times* (as by the laft calculation) then is the object magnified *thirty-fix times* by both. This inftrument is equipt with a mirror, which, by the *angle of incidence*

and *reflection*, throws up light on the *underſide* the object; which object being placed in the focus of a *moveable lens*, has its *upperſide* enlightened alſo.

The *ſolar microſcope* is placed in a round hole in a ſhutter that only admits, into a dark room, a ſmall cone of rays; that theſe rays may be ſent ſtraight through the tube, a plain mirror on the *outſide* is ſo fixed, as to reflect them in; they then paſs thro' a large convex lens; after which, they fall upon, and enlighten the object, which is placed in the focus of a *ſmall magnifier*, through which they carry a large inverted image of the object to a white ſheet, placed at any diſtance for its reception.

A *refracting teleſcope* may be made of *two convex glaſſes*, viz. an *object glaſs* and an *eye glaſs*, if the focus of the *eye glaſs* be in the ſame part of the tube where the image is formed by the *object glaſs*: but then the image will be inverted and therefore 'tis only ſuitable for celeſtial objects. The magnifying power of this teleſcope is as the focal diſtance of the *object glaſs* to the focal diſtance of the *eye glaſs*: Therefore if the *former* be divided by the *latter*, the quotient will expreſs the magnifying power, and ſhew, that if the focal diſtance of *each were alike*, the magnifying power of the teleſcope would be nothing; and that this magnifying power will increaſe with its length, for the greater the focal diſtance of the object glaſs, the leſs may be the focus of the eye glaſs.

A *refracting teleſcope*, that will ſhew objects in their natural poſture, muſt have *two equal convex glaſſes* added to the eye glaſs, and all three muſt ſtand at double their focal diſtances from one another. As theſe three do but as it were compoſe one eye glaſs, the magnifying power of this teleſcope may be calculated as the laſt.

Dollond's patent teleſcope is formed on the ſame principles, only its object glaſs is much larger, and is compoſed of two joining glaſſes of different denſities, one a *plano-concave*, and the other a *double convex* that fits into

the other's concavity. Thefe make the field of view larger, and, by taking off the coloured rays, the image becomes bright, and quite diftinct: For as the rays which pafs through the *edge* of a *convex glafs* are more *unequally refracted* than thofe that pafs nearer its *middle*, they don't meet in the fame point, but form a circle of prifmatic colours round the image: In *the common telefcope thefe* are partly taken off by a *black plate* fixed in the tube, with an hole through its centre; but the *patent glafs* does this much more effectually.

The *reflecting telefcope* exceeds all others in its *magnifying power* and *portable fize*; and its outward figure confifts of a great and fmall tube, fcrewed into the end of one another. At the bottom of the great tube is placed the large concave mirror, with an hole through its middle. Parallel rays from celeftial objects falling on this mirror, are reflected back by it, and form the *image* a little fhort of the *fmall concave mirror* which faces the hole in the large one. From this image the rays diverge to the fmall mirror, and are from thence reflected parallel, and inverted into the fmall tube, through the hole in the large mirror: here meeting with a convex lens, they are fo refracted as to form the imago in the *fmall tube*. The *image being now brought fo near*, requires nothing but a fingle, or compound *eye glafs* to fend it duly magnified to the retina. Rays from any terreftrial object *will not come parallel* but converge a little; hence the image is formed nearer the great mirror, and therefore a fcrew is fixed to the fmall mirror, on the outfide the tube, to adjuft it to it; and alfo to the *greater or leffer convexity* of different eyes. Dr. Herfchel's reflector is formed on the Newtonian plan, viz. its great mirror is not perforated, and therefore its image is received by a plane mirror placed diagonally within the tube, and which fends that image through the magnifying or microfcopic part fixed perpendicularly in the tube. The excellence of this inftrument confifts in the parabolic *curvature* and *polifh* of its great mirror, which forms the image of the object looked at *fo perfect*, that a magnifying power of 6500 can be applied to it.

This inſtrument is carried to ſtill a greater magnifying and diſtinct power by a mirror of near 5 feet diameter, and of 40 feet focal length, without any obſtructing mirrors, ſo the light even from the moon is too ſtrong for a naked eye to look at through it.

The *diagonal mirror*, for viewing prints, is a pleaſing inſtrument. If a *plane mirror* be placed at an angle of 45 degrees above a print lying horizontal and inverted, it will turn the rays reflected from the print into an horizontal direction to the eye: If then a *large convex lens* be placed between the eye and the mirror, the picture will be prodigiouſly magnified; and if an aſſemblage of *ſhell-work* environ the view between the *print and the mirror*, the picture will have a beautiful frame to it.

The *camera obſcura* is formed on the ſame principles. A *diagonal mirror* is ſet at the ſame angle againſt the landſcape, and reflects it downward through a *convex lens* into a *dark box*, where it is painted on a *white paper* placed in the focus of the lens, and on which a hand put into the box may draw the landſcape to the minuteſt exactneſs.

The *opera glaſs* is alſo formed of a ſmall diagonal mirror, which ſends the rays through a convex glaſs to the eye. Through this a gentleman may look at a diſtant lady in the company, and the lady know nothing of it.

The *magic lanthorn* is formed on the ſame principles as the *ſolar microſcope*; a candle ſupplies the place of the ſun; and having its rays tinged with the colours of *tranſparent figures painted on glaſs*, throws them through two convex lenſes on a white wall in a dark room, prodigiouſly magnified. Argand's Lamp has improved this inſtrument very much, as well as the lucernal microſcope, common illumination, the ſea lights invented by the author, &c.

LECTURE X.

USE of the GLOBES.

WHEN a ſhip approaches us at ſea, the firſt part of her we ſee is her *upper ſails*, after that we ſee her *lower ſails*, and then the *hull:*——'Tis evident ſhe moves on a round ſurface or we ſhould ſee the whole at a time. In ſailing from capes we loſe ſight of them firſt at the *bottom*, then the *middle*, and at laſt the *top* diſappears. Theſe effects are in all parts of the world. Several perſons have ſailed round the earth. And all the bodies in the ſyſtem are round. Hence we conclude that the *earth is a globe* alſo.

The earth's roundneſs is no more affected by the largeſt mountains, than the roundneſs of a common globe is by a few grains of duſt thrown upon it; for they bear no greater proportion to its bulk. It is 7,970 miles in diameter: Near 100 millions of miles from the ſun: Moves round him in 365 days 5 hours and 49 minutes, at the rate of 60,000 miles an hour; and turns round upon its axis every 24 hours, from weſt to eaſt, which makes all the heavenly bodies ſeem to turn round the contrary way, or from eaſt to weſt.

The particles of which the earth is compoſed would fly into confuſion, if not held together in the form of a globe by the *power* of *gravitation.* 'Tis this power which gives *weight* to all bodies, or that tendency they have towards the center of the earth. Hence the general *top* of the earth becomes its whole ſurface, and the general *bottom* its center. The *Antipodes* are therefore as much

on the top as we. But as the parts of the earth are loofe, the violent motion it has on its axis will in fome degree overpower even the force of gravity, and accumulate more matter round the *Equator*, becaufe the *centrifugal force* is greateft there; hence the true figure of the earth is an *oblate fpheroid*, or like an orange, 35 miles more in diameter at the equator than at the poles. This was proved by an actual menfuration, and is explained by the whirling rings.

This oblate figure proves its *diurnal motion*; if it was at reft it would be neceffarily a perfect fphere. We perceive not this motion, becaufe the *air* in which we live, partaking of the general gravitation, is carried round along with the earth. When a fhip turns round, if we look out at the cabin windows, we believe ourfelves at reft, and the neighbouring country turning round us; ——we are deceived in like manner in the motion of the earth.

Where there is no reflection from contiguous objects, a globe can but be *one half* enlightened by a luminous body; hence, if a globe turns round, there muft be a fucceffion of light and darknefs, or day and night, to its inhabitants.

Had a globe no other motion, there could be no variety in its feafons or length of days. As gravity decreafes according to the fquares of the diftances, it follows that if one body move in an oval round another as its centre of motion, the fquare of its periodical times will be as the cube of its diftance from that body; this holds precifely with regard to the planets and their moons. The planets fometimes appear to *ftand ftill*, fometimes to *go backwards*; this muft always be the cafe where one body moves nearly in the fame plane, and circular within the orbit of another moving body.——The eclipfes of Jupiter's fatellites appear later to us by 16 minutes at one time of our year than at another. 'Tis matter of obfervation, that all the planets revolve round the

ſun. From all which we are certain that the earth goes round the ſun, and not the ſun round the earth.

We know the path our earth deſcribes in the heavens, by obſerving *that* which the ſun ſeems to deſcribe in the oppoſite part of the heavens. We find one ſtar without any apparent motion, ſituated 23 degrees and a half from the axis of this orbit, and which is occaſioned by being nearly oppoſite to one of the poles of our earth, and thence called the polar ſtar; hence we diſcover that ſublime contrivance the inclined axis of the earth, which keeping always *parallel to itſelf*, occaſions the different ſeaſons, and different lengths of day and night; diffuſing equally, over the face of both hemiſpheres, the bleſſings of the ſun.

The axis ſo diſpoſed will neceſſarily bring the northern and ſouthern parts of the earth alternately to the ſun, therefore when it is ſummer in the *north* it will be winter in the *ſouth*, and vice versâ. So far on each ſide the equator as the ſun at any time of the year ſhines vertically, is called the *torrid zone*, and it is bounded by two imaginary lines; *that* to the north is called the *tropic of cancer*, and *that* to the ſouth, the *tropic of capricorn.* When the ſun ſhines vertically over the firſt, he muſt ſhine 23 degrees and a half further than the north pole, and will not therefore ſet for many days together to the inhabitants of the *north frigid zone*—but it will be then total darkneſs (the ſame time) to thoſe of the *ſouthern frigid zone*; hence the poles *muſt* but have one day and one night in the year. Theſe two zones (as they are called) are bounded by lines alſo, the north called the *artic*, the ſouth the *antartic* circle. The intermediate ſpaces between the torrid and frigid zones are called the *temperate zones.*

In the northern hemiſphere the *vernal equinox* (or equal day and night in the ſpring) is about the 20th of March; and the *autumnal equinox* is about the 23d of September; in the ſouthern hemiſphere the contrary:

At the equinoxes the ſun ſhines over the equator ; at the *ſolſtices* he ſhines 23 degrees and a half from the equator.

The *meridian* of any place is a ſemicircle paſſing through it, cutting the equator at right angles, and terminating in the poles. The earth's circumference is 360 degrees, each near 70 Engliſh miles, and as the earth turns round on its axis in 24 hours, each meridian revolves 15 degrees in an hour, for $24 \times 15 = 360$. Therefore every place to the *eaſtward* of another has its hours ſooner, if *weſtward*, ſo much later.

The *longitude* of any place is the number of degrees between its meridian, and the meridian of any place, from whence the longitude is reckoned, and is deemed *eaſt* or *weſt* according as it is ſituated. The eclipſes of *Jupiter's ſatellites* afford a method of finding the longitude, thus: Suppoſe an eclipſe of any *ſatellite* happens in London at ſix in the morning, and that it is ſeen at another place at four in the morning, the difference of time is two hours, which anſwers to 30 degrees weſt of London. Theſe obſervations the motion of a ſhip hinders from being made at ſea; and hence may be perceived the extreme utility of a regular time-keeper.

The *latitude* of a place is ſo many degrees as it is from the equator; if to the north, it is ſaid to be in *north latitude*; if to the ſouth of the equator, in *ſouth latitude*; hence by the lines of latitude and longitude, the face of a globe is covered with *imaginary ſquares*, by which the ſituation of every ſpot on the face of the earth is as exactly aſcertained as the parts of an eſtate are by its hedges and ditches.

The *rational horizon* of a place extends 90 degrees from the place on all ſides. The *ſenſible horizon* is the boundary of the obſerver's ſight on all ſides.

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The *ecliptic* is that circle in the heavens through which the earth makes its revolution round the fun; and it is diftinguifhed by confpicuous affemblages of fixed ftars, called figns or conftellations, fuch as *Aries*, *Taurus*, *Gemini*, *Cancer*, *Leo*, *&c.* The *zodiac* extends to eight degrees on each fide of the ecliptic, and with it round the heavens.

The four continents of the earth are, *Europe*, *Afia*, *Africa*, and *America*. The oceans are the *Northern*, the *Atlantic*, the *Ethiopic*, the *Indian*, the *Pacific*, and the *Southern Oceans*. The unknown parts of the earth contain 160,566,276 fquare miles; the inhabited parts 38,990,569, *i. e.* Europe 4,456,065; Afia 10,768,823; Africa 9,654,807; America 14,110,874. In all 199,556,845; which is the number of fquare miles on the whole furface of our globe.

When a round ball has the different countries, kingdoms, towns, and rivers delineated upon it agreeable to their fituations, it is a reprefentation of the earth. If an hollow fpherical ball could have the fixed ftars properly marked on its infide, with the fun, moon, and planets, it would be a reprefentation of the heavens to an eye placed in its centre; but this being inconvenient, the fixed ftars are placed on an opaque globe, and the fun and planets reprefented by patches placed on the ecliptic, becaufe they are continually changing their places.

LECTURE XI.

On the MOON, *&c.*

THE *moon* is no planet, but only a fatellite, or an attendant on the earth. The farther any planet is from the fun, the more occafion it has for fuch an help to its light; hence Mercury and Venus are without moons, as being near the fun; but Jupiter has four, and Saturn five, (now known to be feven) becaufe of their diftance from it.

The moon's face abounds with great *inequalities*, and hence fhe reflects a more chafte and agreeable light than if her furface was fmooth. She always keeps the *fame face* towards us (fome fay becaufe the quality of that fide of her is more adapted to catch the attraction of the earth than the other) and confequently muft turn once round on her axis, while fhe goes once round the earrh in her orbit. Her *periodical revolution*, or time of going round from one point of her orbit to the fame point again, is 27 days 7 hours 43 minutes: But her *fynodical revolution*, or time from change to change, is 29 days 12 hours 44 minutes;——this difference is caufed by what the earth has advanced in the ecliptic during that time, which is 29 one-tenth degrees. (*Illuftrated by the Orrery and Ferguſon's paradox.*

The moon's mean diftance, found by her parallax, is 240,000 miles. Her diameter is 2180 miles,——and fhe moves about 2290 miles every hour.

The *moon* has no light of her own, but only reflects the beams of the ſun, as a poliſhed body does the light of a candle;—hence, as ſhe is a globe, we muſt ſometimes ſee *more* ſometimes *leſs* of her enlightened ſide, *viz.* when ſhe is between us and the ſun, her dark ſide is towards us, and therefore ſhe diſappears; as ſhe advances forward we ſee a ſmall part of her enlightened ſide, and call it the *new moon*; becauſe next evening ſhe is got a few degrees farther to the eaſt and we ſee *more* of her illumin'd ſide;——every evening we find her advanced till ſhe riſes in the eaſt in oppoſition to the ſun in the weſt, and then her whole enlightened face is towards us, and we ſay ſhe is at the *full*; her decline is from the ſame reaſons; and a ball over a gate enlightened by the ſun conveys a clear idea of both. (*Illuſtrated by the Orrery.*)

The earth is a *moon* to the moon, waxing and waning as ſhe does; it appears 13 times as large to the lunarians as the moon does to us, affording them both an uſeful and an amazing ſpectacle, for its continents and ſeas may be plainly perceived by them, as well as its rapid motion round its axis. (*Proved by the Orrery.*)

The planets as well as their ſatellites being *enlightened by the ſun*, muſt caſt *ſhadows* towards that part of the heavens oppoſite to the ſun. Was the earth bigger than the ſun, its ſhadow would ſpread and extend far beyond the orbit of Mars, and conſequently *eclipſe him*, for he is but 42 millions of miles from the earth, when they are in conjunction; but the earth's ſhadow never reaches him, therefore it muſt end in a *point* much ſhort of that diſtance; another proof how much the ſun is bigger than the earth: But the moon is eclipſed when ſhe falls into the earth's ſhadow, which, for the reaſons above, can never happen but when ſhe is at the *full*, becauſe that is the only time when ſhe is oppoſite to him; but was ſhe a *luminous body* ſhe could not be darkened by the earth's ſhadow. (*Proved by a real ſun and moon.*)

The ſun is eclipſed when the moon paſſes directly between him and any part of the earth; this can only happen at the *change of the moon.* *(Proved in like manner.)*

Was the moon's orbit in the *plane* of the earth's path round the ſun, ſhe would be eclipſed every time ſhe came to the *full*, and would eclipſe the ſun every time ſhe came to the *change*; but one half of her orbit is on the *north ſide* of the eclipſe, and the other half on the *ſouth ſide* of it, and muſt therefore cut the ecliptic in two oppoſite points, called tne *moon's nodes.* The angle of this orbit with the ecliptic is 5 degrees and one third. *(Shewn on the Orrery.)*

When the moon is at full, above 12 degrees from either of theſe nodes, ſhe paſſes clear of the earth's ſhadow, and cannot be eclipſed; and when ſhe changes above 18 degrees from either of them, ſhe paſſes either above or below the ſun, and therefore cannot eclipſe him: But if ſhe be at full or change within thoſe diſtances, then an eclipſe happens, and if ſhe be *in* the node, the eclipſe is central. *(Explained by the Orrery.)*

If theſe nodes kept always in the *ſame* ſigns of the ecliptic, the ſun and moon would always be eclipſed in the ſame *places* and at the ſame *time* every year:—but the eclipſes *fall back* every year from the eaſt to the weſt, in ſuch a manner as to prove that the moon's orbit *moves backwards* 19 degrees one-third every year, ſo that in 18 years and 225 days there is a period or reſtitution of the ſame eclipſes; and they then appear in the ſame places and the ſame time as before. *(Illuſtrated by the Orrery.)*

The earth and moon are chained to one another as it were by their *mutual attraction*, which, like the ſun and planets, is in proportion to their quantities of matter. If an heavy and light ball be tied to the two ends of a ſtring a yard long, and toſſed up into the air, they will form to themſelves a centre of gravity. On this centre of gravity the earth and moon revolve in *equilibrio*, and its diſtance from their centres is inverſely as their quantities of mat-

ter, *viz.* 6000 miles from the earth's; confequently the centre of gravity forms the *real orbit*, and makes the earth 12000 miles nearer the fun at the time of *full moon*, than at the time of change. This is demonftrable by the fun's appearing fo much larger at the full than at the change of the moon. *(Proved by the whirling tables.)*

The further any part of the earth is from this centre of gravity, the greater is its tendency to fly off in a tangent, —therefore the *fide of the earth* which is turned away from the moon has a greater *centrifugal motion* than its *center* has: and this *centre* a greater than *the fide* next the moon. At the earth's *centre*, the moon's attraction balances the centrifugal force, but muft be *ftronger* than the centrifugal force of the *fide of the earth next her*, and *weaker* than the centrifugal force of the *fide fartheft from her*. As the moon's attraction is greater than the centrifugal force on that fide of the earth next the moon, of courfe the *tide* will rife on that fide: But as the centrifugal force on the oppofite fide is greater than the moon's attraction, the tide will alfo rife on that fide; hence the reafon of *two* tides in 25 hours. *(Proved by the tide table.)*

The fun agitates the water in proportion to the moon, as 3 to 10; therefore, when the fun and moon draw in the *fame direction*, they caufe a *fpring tide*, and this happens at the change of the moon. If the earth had no moon, the fun would caufe a *fmall tide* in its oceans, therefore at the full of the moon fpring tides happen as well as at the change, for the fun's centrifugal tide being reinforced by the moon's attraction, and the moon's centrifugal tide by the fun's attraction, fpring tides happen both at full and change of the moon; but at the quarters, when they attract in *contrary directions*, they deftroy the effects of each other in a degree, and then we have *neap tides*. At the *equinoxes* the fun and moon being both on or near the equator, their attraction is more in a *line* than at moft other feafons, hence the *prodigious tides* which generally follow thefe feafons, both in the air and fea. A planet

alſo falling in conjunction with the ſun and moon, will increaſe the tides ſtill more. *(Shewn by the tide tables.)*

The *air* being a fluid much lighter than water, is more affected by the moon's attraction. Hence at the full and change the barometer is moſt affected; and ſome ſay lunatics are more affected at thoſe ſeaſons.

To the inhabitants ſituated at a conſiderable diſtance from the equator, the *different parts* of the ecliptic riſe at very *different angles* with the horizon. In northern latitudes, the ſigns *Piſces* and *Aries* riſe with the *ſmalleſt angles*; *Virgo* and *Libra* with the *greateſt*; therefore when the moon is in *Piſces* and *Aries* ſhe muſt riſe nearly at the *ſame hour* for ſix or ſeven days together. In *winter* the moon is in thoſe ſigns about the time of her firſt quarter, but as ſhe muſt then riſe about *noon*, *that* riſing is not taken notice of. In *ſpring* the moon is in them about her *change*, but as ſhe then gives *no light*, her riſing is alſo unnoticed. In *ſummer* ſhe riſes in *Piſces* and *Aries*, in her *third quarter*, about twelve o'clock at night, conſequently the phænomenon is ſeldom *then* regarded; but in *autumn* thoſe ſigns are oppoſite to the ſun, and therefore the moon muſt be *full* in them, and, very uſefully for the farmers, riſes in their harveſt immediately after ſunſet for ſeveral evenings together, and thence acquires the name of the *harveſt moon*. *(Proved by the Orrery and Globe.)*

LECTURE XII.

ASTRONOMY.

THE planets are retained in their orbits by the *power of gravity*:—but as the ſun is by far the largeſt body in our ſyſtem, if no other power acted on them they would be *drawn down to the ſun*. All bodies therefore that move in curves, as the planets do round the ſun, muſt be acted upon by *two principles*; and motion being *rectilineal*, we ſuppoſe the Almighty gave each planet this kind of impulſe at its creation, ſo that between one power *drawing to the centre*, and another *acting perpendicular to it*, the planets are impelled in eliptic orbits round the ſun, as a pebble tied to a mill-ſtone, and thrown from the hand, would revolve round the mill-ſtone. An idea of this is given by a ball impelled ſingly in a ſquare in two directions, one perpendicular to the other; when they both act they give the diagonal of the ſquare, &c.

Our ſyſtem muſt be conceived as within the concave ſphere ſeeming to be formed by the *fixed ſtars*, and the *ſun* as near the centre of it, an huge globe of fire, near a million of miles in diameter, and near 100 millions of miles from the earth, according to calculations made from the tranſits of Venus.—He turns round on his axis in 25 days and 8 hours, as may be ſeen by ſpots on his face; and was no doubt intended to give light, heat, and vegetation to the ſix primary and ten ſecondary planets which revolve round him.

All thefe planets move round the fun from *weft by fouth, to eaft*, in orbits nearly circular, and almoft in the fame plane. The *comets* move in all manner of directions, in orbits which are very long ellipfes, much inclined to one another, and to all the orbits of the planets. The tails of comets are only thin vapours; for if they were flame no ftar could be feen through them.

The time in which any planet goes round the fun is the *length of its year*, and the time on which it turns round on its axis, is *the length of its day and night* taken together, as reprefented on the Orrery.

The neareft planet to the fun is *Mercury*; he goes round him in 87 days 23 hours, is about 3000 Englifh miles in diameter, and diftant from the fun 42 millions of miles; he moves in his orbit about 100 thoufand miles every hour; the length of his days and nights are unknown, being but 56 times the fun's apparent diameter from him; he fets and rifes too near the fun for any obfervations to be made of his fpots.

Venus goes round the fun in 224 days 17 hours, her diameter is near 7,900 miles, her diftance from the fun is 79 millions of miles, her hourly motion in her orbit is 69 thoufand miles, and fhe turns round on her axis in 24 days 8 hours of our time. By her axis inclining 75 degrees from a perpendicular to her orbit, (agreeable to the older aftronomers), fhe has two fummers and two winters at her equator.

Her orbit alfo deviates three one-half degrees from the plane of the ecliptic, fo that fhe has two nodes, or places where fhe croffes the ecliptic, one in the 14th degree of Gemini, and the other in the 14th of Sagittarius. If the earth happens to be in thofe figns when *fhe* is, then we fee her tranfit over the fun's face, a phænomenon which happened the 1ft of April, 1761, and gave the aftronomers

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the opportunity of calculating the ſun's parallax, *viz.* 7″ 40‴ and of conſequence his diſtance, as well as that of the planets.

The *earth* is the next planet in the order of the ſyſtem.

Mars, ſtill higher in the ſyſtem, is 167 millions of miles diſtant from the ſun, moves at the rate of 47,000 miles an hour, goes round the ſun in 678 days, and turns round on his axis in 23 hours 39 minutes and 22 ſeconds, at a medium, according to Dr. Herſchel's obſervations on a ſpot on the face of Mars; though he obſerves his motion not to be regular. He is about one-fifth as large as our earth; his *red appearance* is ſuppoſed to be occaſioned by a groſs thick atmoſphere with which he is ſurrounded, and which is ſuppoſed to ſupply his want of a moon.

Jupiter, the largeſt of the planets, is 570 millions of miles diſtant from the ſun, and above 400 millions from our orbit; he moves round the ſun in about 12 years of our time, at the rate of 30,000 miles per hour; he is near 90,000 miles in diameter (*i. e.* near 1000 times as large as our earth) is accompanied by four moons, ſome bigger and ſome leſs than the earth, which revolve round him as our moon does round us; and the faint ſubſtances on his face, called his belts, are ſuppoſed to be parts of his atmoſphere drawn into lines by his exceeding quick revolution on his axis, which is once in 9 hours 49 minutes.

Saturn, the ſecond in magnitude, and hitherto conſidered the moſt diſtant of all the planets, is 949 millions of miles from the ſun;——near 70,000 miles diameter; moves at the rate of 18,000 miles an hour,——but is too remote for his ſpots to be ſeen. He is equipt with *five moons*, (Dr. Herſchel has ſeen two more) beſides *a broad luminous ring* which alſo reflects the ſun's light ſtrongly

upon him. This planet is near 30 of our years in making his revolution round the ſun.

The *Georgian Planet* (or rather the *Herſchel*) ſo called by its ingenious and indefatigable diſcoverer Dr. Herſchel; was firſt ſeen near one of the feet of Gemini; its year is calculated to be 82½ of ours, its diſtance twice that of Saturn from the ſun, and its ſize 100 times as large as our earth.

Theſe calculations are the lateſt and moſt accurate that have been made; they are given in round numbers, to eaſe the memory, and are founded on *mathematical* as well as *occular* certainty.

By an *attempt* at the ſame kind of calculation to find the diſtance of the *fixed ſtars*, 'twas found *that the whole diameter of the earth's orbit would not make a parallax* or *angle with the neareſt of them!* Their diſtance therefore muſt be inconceivably great. Light diminiſhing as the ſquares of the diſtances increaſe, the ſun's rays therefore cannot enlighten the fixed ſtars; and a teleſcope which magnifies 400 times does not ſenſibly magnify them; 'tis therefore highly probable they are *ſuns* like ours, ſhine by their own unborrowed luſtre, were not intended for our ſervice, but to give light, heat, &c. to ſyſtems of worlds of their own, formed probably for the ſame purpoſes as ours, though too remote for our eyes aſſiſted by the beſt glaſſes to perceive. We find the worlds of our ſyſtem covered with *continents*, *ſeas*, *hills*, *&c.* Who can doubt therefore but they are inhabited, as well as all the worlds of the other ſyſtems? How much too big is this idea for the human imagination! By the lately improved teleſcopes thirty thouſand of theſe ſuns have been found more than the naked eye can perceive! Were our glaſſes ſtill better, we ſhould, no doubt, find more ——'tis not improbable there may be ſtars ſo diſtant that their light has not reached the earth ſince the creation. Many of thoſe ſtars appear double, and coloured green, blue, red, violet, &c.

Let us on the wings of imagination then launch into the immenſity of ſpace, and behold *ſyſtem* beyond *ſyſtem*, *above us*, *below us*, to the *eaſt*, the *weſt*, the *north*, the *ſouth!* Let us go ſo far as to ſee our ſun but a *ſtar* among the reſt, and our ſyſtem itſelf as a point, and we ſhall but even then find ourſelves on the *confines of creation!* How inadequate then muſt be the utmoſt ſtretch of human faculties, to a conception of that amazing *Deity* who made and governs the whole! Should not the narrow prejudices, the littleneſs of human pride ſoften into humility at this thought!

EXPLANATION

Of ſuch uncommon WORDS as cannot, without affectation, be omitted in this COURSE.

ABSORB, to drink in.
Acid, ſour.
Accelerated, haſtened, hurried forward.
Accumulate, to heap up.
Adheſion, the ſticking together.
Affinity, related to, having an affection for.
Alkali, fixed ſalt or ſubſtances efferveſſing with acids.
Analogy, likeneſs, proportion.
Apparatus, inſtruments for experiments.
Attraction, a drawing together.
Axis, an axle on which any thing turns.

C

Capillary, ſmall as an hair.
Calcs, the earth or cinders of a metal.
Centrifugal, a direction given to a body different from that inclining to the centre.
Centripetal, tending towards the centre.
Coheſion, clinging or ſticking together.
Collateral, lying ſide by ſide.
Compreſs, to ſqueeze together.
Concave, ſpherically hollow.
Condenſe, to bring the parts of matter cloſe together.
Contact, touching each other.
Convex, ſwelling ſpherically outwards.
Converge, to draw towards a point.
Chryſtallization, ſalts ſhooting into their uſual forms.
Cylinder, like a rolling ſtone.

D

Denſity, compactneſs, cloſeneſs.
Diagonal, the line running between oppoſite corners of a ſquare.
Diverge, to ſpread out.

E

Ebullition, a bubbling like boiling water.
Elaſtic, having a ſpring.
Electrometer, an electrical gage.
Efferveſcence, a ferment or diſcharge of fixed air, a waxing hot.
Ellipſes, an oval line or ſurface.

F

Fibre, a ſmall ſtring.
Flaccid, lax, looſe, or flabby.
Fulcrum, a prop or point of ſupport.
Frigorific, chill, or cauſing cold.

G

Gravity, weight, or the tendency one body has to another.

H

Hemiſphere, half a globe.
Hermetically ſealed, tube cloſed with melted glaſs.
Hypotheſis, a ſuppoſition.

I

Immerſe, to dip or plunge in.
Impel, to drive onwards.
Incompreſſible, not to be ſqueezed into leſs compaſs.

Incidence,

Incidence, a falling or lighting on.

Insulate, to cut off, like an island.

Interstices, intervals, or intermediate spaces.

L.

Lateral, sideway.

Longitudinal, lengthwise.

M.

Medium, a means of conveyance.

Momentum, the moving force of a body.

N.

Nomenclature, a system of relative names given to chemical substances.

O.

Oblique, crooked, inclining.

Orbit, the tract described by a planet round the sun.

Oxyginous Principle, dephlogisticated air.

P.

Particles, exceeding small parts.

Percussion, striking, or the effects of a stroke.

Perforate, to bore through.

Piston, a moveable plug, just fitting a pipe.

Phænomenon, an appearance in nature.

Phlogiston, one of the principles of inflammability in bodies.

Pores, small interstices in bodies.

Preponderate, to descend, be heavier.

Projectile, a body in motion, cast or thrown.

R.

Rarefy, to thin, to make dense matter weaker.

Reflection, rebounding back, returning.

Reciprocal, mutual, relative.

Refract, to incline, or break.

Reservoir, a cistern, or head for a reserve of water.

Reverberate, to beat back, to echo.

Rotation, returning about.

S.

Saturation, absorption, drinking in, &c.

Secrete, to separate.

Sensorium, the seat of perception in the brain.

Solution, a solid dissolved in a fluid.

Species, sort or kind.

Specific, peculiar, bulk for bulk.

Spiral, like a rope coiled round.

Subterraneous, within the earth.

Sublimation, distillation of dry substances.

Syphon, a bent tube, or crane.

System, composing a general structure.

T.

Tangent a straight line touching the circumference of a circle.

Tangible, capable of being felt or handled.

Tenacity, a clinging together.

Tension, a stretching out.

Transit, the passing of a planet before the face of another, or the sun.

Tube, a pipe.

V.

Vacuum, a space devoid of air.

Valve, a trap door, letting a fluid come thro' but not return.

Velocity, the moving speed.

Vertex, the point at the top of any thing.

Vibrate, to swing as a pendulum.

Undulating, moving in waves.

Volatile, subject to evaporate or fly off.

F I N I S.